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Engineering and Mining Journal

JANUARY, 1934

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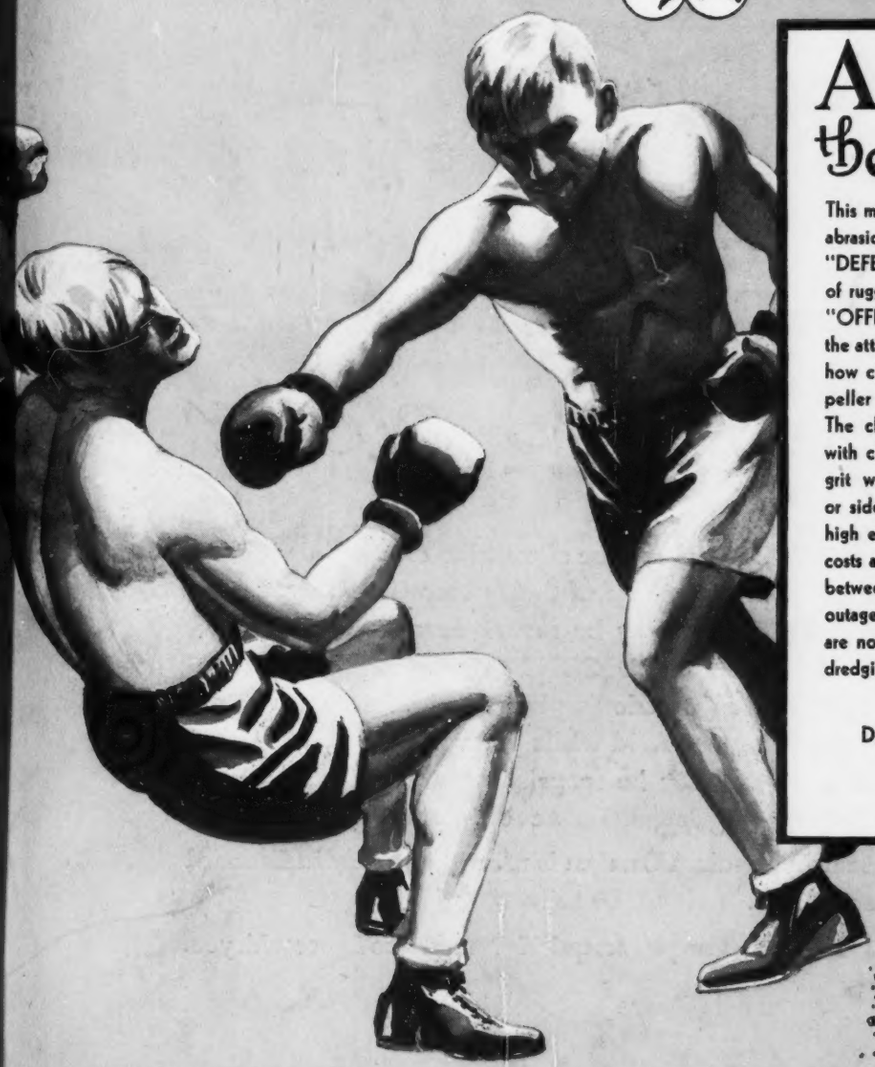

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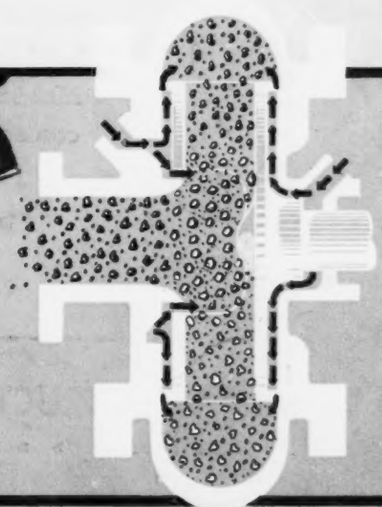

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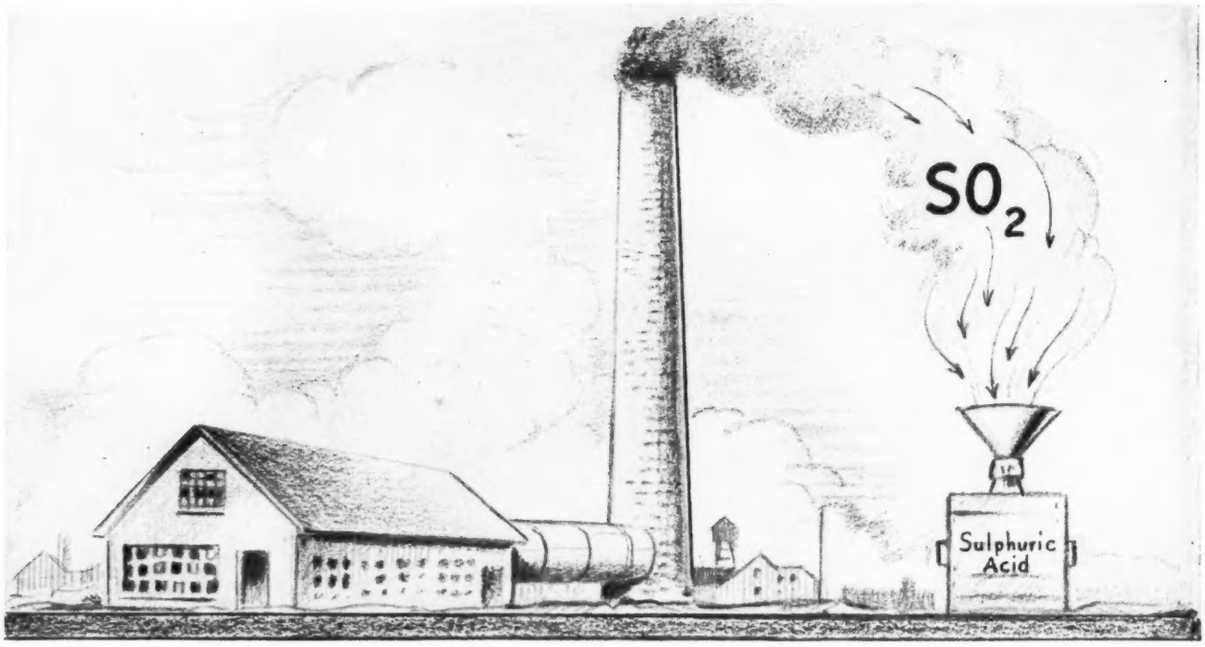

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Engineering and Mining Journal

WITH WHICH IS CONSOLIDATED ENGINEERING & MINING WORLD

H. C. PARMELEE, *Editorial Director*

JANUARY, 1934

JANUS, double-headed deity in Roman mythology, was the god of entrances and beginnings — "the spirit of opening." The beginning of the year, January, was sacred to him, and an annual festival was celebrated in his honor. On Roman coins and medallions he is represented with two bearded faces looking in opposite directions, but in a statue recovered in Pompeii he was both bearded and beardless. As the patron of all beginnings, the double head of Janus fitly graces the first page of a new volume of *Engineering and Mining Journal* in a new year for the mining industry. But there is a further fitness in selecting the Pompeian representation as a symbol for the opening of 1934. By contrast the heads suggest age and youth, tradition and modernism, past and future, the old régime and the new, the sober, backward glance and the hopeful, forward look.

Inspiration is to be derived from the second of each of these contrasting characteristics, symbolized in the beardless head of Janus. At this critical juncture in the world's affairs far more interest attaches to future opportunity than to past achievement. Economic evolution has entailed such radical changes that even the pattern is unfamiliar, and constructive thought of the highest order must be given to the solution of new problems and the establishment of a new order.

And so, in planning this issue, the editors have discarded the traditional review of the past year, and have reversed the custom by presenting a series of articles that are distinctly forward looking. The time is particularly favorable to the conception expressed. In common with others, the mining industry has been passing through difficult times that have kept engineers' minds too close to their jobs. To a large extent they have been occupied with routine matters and have not been free to think, investigate, or plan.

But with the inevitable change in conditions the entire industry will be confronted with new problems, technical and economic. Recovery will demand every ounce of resourcefulness and ingenuity that can be commanded. Custom and tradition will be poor guides for the future. New landmarks will have to be erected. It is in this spirit that we invited a group of engineers to contribute to this issue. We encouraged them to present new ideas, new thinking concerning unorthodox techniques, social and industrial; to suggest new avenues of research and investigation that ought to be explored; to take a critical look at economic conditions in the mining industry and to suggest programs of future action. This they have done generously, and the mining industry is indebted to them for new guideposts for the future.

Both the technologic and economic aspects of the mining industry are treated in the articles that follow. New technology based on research and critical examination of existing practice offers hopeful opportunities for improvement in efficiency and cost of winning metals. But these advantages will in no sense offset any failure on the part of management to adopt sound economic policies. Hence the urgent necessity to get as clear a picture as possible of the future of the mining industry. The economic problems confronting management are more puzzling and baffling, and yet more vital, than those of technology. And if, for the moment, the future seems to be symbolized by a large question mark, that very condition is a challenge to face the facts, to shun the mistakes of the past, to adopt economic policies that are as sound as the technology on which the industry is based, and to chart the best possible course toward recovery.

The outlook for the precious metals seems favorable, but the non-ferrous metals are beset with difficulties and uncertainties. Nevertheless, if wise and honest counsel prevails, the mining industry can be led through this period of economic readjustment into a prosperous future. Such is the wish and the hope of *Engineering and Mining Journal* for the industry in Nineteen Thirty-four.

Silicosis Legislation Looms On the Industrial Horizon

IN THE course of compiling information on which to base the article on silicosis compensation that appears in this issue, a letter inquiring into the status of silicosis legislation was addressed to the department of labor of each of the several states comprising this country. Lack of replies from a number of states, including a few of the more important metal-mining states, made a detailed tabulation of the statements received inadvisable in the article. Some of the individual reports, however, are particularly interesting. The Deputy Commissioner of Labor for New Jersey, for instance, wrote "Health injuries caused by silicosis do not come under the operation of the workmen's compensation laws in the State of New Jersey. There is a strong feeling, however, on the part of many people in this State, that silicosis should be made compensable and an intelligent medical board selected by the State to pass judgment on silicosis cases in order to remove decisions of this kind from the controversies that usually arise when expert medical testimony is purchased by employer and employee." West Virginia's Commissioner of Labor stated: "Occupational diseases are not compensated under our State compensation laws. A bill was introduced in the 1933 session of the Legislature providing for compensation for silicosis, classifying it in first, second, and third stages, and making lump sum awards according to the stage designated. The bill was opposed on the ground that it was the first step toward having occupational diseases included in our compensation laws. The bill was defeated, but no doubt efforts along this line will be continued in the next session.'

These quotations present but two examples of many received that strikingly disclose the growing interest attaching to industrial dust hazards. Silicosis, as an occupational disease, seems, at the moment, to have associated with it many inequitable features for both employer and employee. A speedy solution of the various problems involved would assuredly be to the ultimate advantage of the mining industry.

U. S. Geological Survey and Bureau of Mines in Eclipse

IN VIEW of the necessity for paring budgets and housing new governmental agencies, such as the National Recovery Administration and the Public Works Administration, the scientific bureaus of the Government in Washington are being forced to make inequitable contributions to the federal program of economy and recovery. In two of these bureaus, the Bureau of Mines and the U. S. Geological Survey, the mining industry is particularly interested. At present they are receiving traditional stepchild treatment. Their almost total eclipse by the NRA and PWA has alarmed their friends lest their immediate decline and disintegration threaten their future usefulness when better times return. The Bureau, having previously been moved from the Department of Commerce to the Department of the Interior, has since been broken up and housed in four or five separate places in Washington, and our information is that the U. S. Geological Survey must vacate its quarters in Interior to make way for one of the new agencies in the recovery program.

Since 1929 Congressional appropriations for the work of the Bureau of Mines have diminished, until the amount now approved by the Department of Commerce for 1934 is less than one-third of that available in 1929. Inevitable results have followed. Personnel has been reduced by one-third. Nine out of eleven rescue cars have been sidetracked. Field stations have been closed, cooperative health service has been discontinued, and training in safety and first aid has been greatly curtailed. The Survey also has been obliged to reduce the scope of its operations. Ninety-day furloughs without pay for the technical staff are part of its economy program.

The future welfare of these two organizations probably will not be finally determined until the President acts. He has appointed a committee of scientists and engineers to study and report upon the activities and functions of all the scientific agencies of the Government. A subcommittee is giving attention to the Bureau of Mines and U. S. Geological Survey. An early report of this subcommittee is greatly to be desired, so that the welfare of these bureaus and the scope of their activities can be fairly and impartially determined. One step seems logical, and that is to transfer the Bureau of Mines back to the Department of the Interior, where it was formerly with the Geological Survey.

■

Historical Summary

Engineering and Mining Journal was founded in 1866 as the *American Journal of Mining,* the title being changed in 1869. Publications with which *Engineering and Mining Journal* has been consolidated comprise: *Coal and Iron Record* (1875); *The Mining Review* (1877); *The Polytechnic Review* (1879); *Mining and Metallurgy* (1902); *The Mining Magazine* (1906); *Mining and Engineering World* (1917); *Mining and Scientific Press* (1922); *Engineering and Mining World* (1932).

The following have served as editors in chief of *Engineering and Mining Journal* and its predecessor publications: G. F. Dawson (1866-67); R. W. Raymond (1867-74); R. W. Raymond and R. P. Rothwell (1874-89); R. P. Rothwell (1890-1901); D. T. Day (1901-02); T. A. Rickard (1903-05); W. R. Ingalls (1905-19); J. E. Spurr (1919-27); A. W. Allen (1927-33); H. C. Parmelee (1933—).

The editorial staff of *Engineering and Mining Journal* comprises: H. C. Parmelee, editorial director; A. H. Hubbell, H. D. Keiser, associate editors; W. N. P. Reed, J. B. Huttl, assistant editors; H. H. Wanders, market editor; G. J. Young, consulting editor.

What of the Mineral Industry's Future?

Many Questions . . . . The Answers Difficult

Thomas T. Read

Professor of Mining Engineering, Columbia University

THE PUBLISHER of a great London newspaper is said to have replied to a man who told him of a mistake in the paper of the day before, that he was not interested in that, but would deeply appreciate it if he could be warned of a mistake that was about to appear in the next day's paper. The custom of reviewing, at the beginning of each year, the events of the past one finds its principal usefulness as a possible guide to the year just starting. Logically it would be better simply to attempt to forecast and let the past go, but that requires so much courage as to verge on the foolhardy. Events have a disconcerting way of turning out differently from the way we expected them to, so cautious people prefer merely to review the past and let others make their own deductions as to the future.

But inasmuch as the present is a time of great uncertainty, and since, in the past few years, we have learned how fallible was the judgment of many great men who had been regarded as almost infallible, it no longer seems quite so necessary to avoid committing oneself as to the future, lest one prove wrong. Consequently, when the editor asked me to attempt a forecast of what the future may hold for the mining industry I agreed, with many misgivings, to make the attempt.

The most obvious feature at present is that, after nearly a century of rapid and almost uninterrupted growth in the demand for and use of many mineral commodities, we have had several years of greatly curtailed consumption. Our energy supply, in the United States, from mineral fuels and waterpower, that had grown from 14,182 trillions of B.t.u. in 1909 to 26,534 in 1929, shrank to 17,841 in 1932. Iron-ore production, that averaged 58,500,000 tons yearly during the decade 1921-30 declined to less than 10,000,000 tons in 1932. Some mineral commodities did not fare so badly; gold production in 1932 showed a small increase and bromine production in 1932 showed a 400 per cent increase over the record for 1928. But we never have produced much bromine, and, broadly speaking, the greatest declines have been in those things of which we produce the most, or have produced for the longest time.

Everyone would like to cast a horoscope to find out whether these reduced rates of consumption are likely to persist for some time, or whether, after only a brief halt, they will resume their march toward ever higher levels. Although I am a seventh son, I am unable to do that, and will therefore attempt no more than to set forth what seem to be the principal factors likely to be involved. Quite possibly I may prove wrong, but the responsibility for my making so hazardous an attempt is the editor's.

The rapid recent growth in the consumption of mineral commodities seems to stem from the growth in energy consumption. Our people were doing lots of work and needed much raw material to work on. Half the work of the world was being done in the United States by 7 per cent of the world's population. Barring such things as nickel, tin, and tungsten, about half the world's production of mineral was also in the United States. Except for petroleum products and manufactures of iron and other metals, we exported very little of what we produced from mineral of domestic origin. We were typically making things for our own use; for a time we seemed to have no difficulty in exchanging them and nearly everyone was happy. The age-old fight against privation and want seemed nearly won.

When the decline in consumption began, it was not because people had ceased wanting things made from minerals, but because they could no longer negotiate the acquiring of them. The machinery of distribution had broken down. The spiral that had been circling outwards began to circle inwards. Work stopped because the products of work could no longer be exchanged as freely as before, and every man who stopped work was out of the market, to a considerable degree, for the products of some other man's work. Railroads stopped buying new equipment and bought less coal, people stopped building new houses and office buildings, fewer people bought new automobiles, and so on. If the distribution of the products of work prior to 1929 was sound, there is no basic reason why we cannot go back to the 1929 basis of production and consumption. But was it sound?

When we ask that question we have to consider the effects produced by the use of money, which seem to puzzle the clearest-minded. If a railroad would accept part of a shipment of coal in payment of the freight on it, and the producer of coal would accept part of the products made by the consumer of coal in payment for it, the only limit to the amount of business they could do with each other would be their relative ability

to make use of each other's products. No one would suggest that the human beings who produce coal have passed their limit of the use they can make of food, clothing, houses, automobiles and radios; we know that for years strenuous efforts have been made to keep many of them up to the margin of existence. Everybody sees clearly that the markets for all sorts of products of work are somewhat curtailed because coal miners and steel workers are unable to consume them on the scale they would like, but we are baffled by the problem of what to do about it. The NRA offers the simple solution of raising wages; people who get more wages can buy more, and so, it is hoped, the spiral will be turned outward again.

Though the temptation to discuss the probable effect of recent money policies is strong, it must be resisted here, since it has been and is still being discussed by many others at considerable length. My personal belief is that increasing wages, intending to increase prices, as a means of stimulating general activity, including mineral production, can only work through decreasing the percentage which fixed charges constitute of the total gross of prices. Increasing wages without increasing prices can only work through increasing consumption and thus making the total of fixed charges spread over a greater number of units of output. Perhaps someone knows whether the uncertainty that such changes necessarily produce will curtail general activity less than the changes would be likely to increase it, but I do not know whether it will or not.

Price Level and Competition

Let us therefore pass over, as too complicated to go into in detail, the probable effects on the mineral industry of a general increase in the price level. A mill man can readily see they are likely to be as intricate and complex as the effect on his mill operation would be if he decided to grind all his ore to pass 200 mesh instead of the 100 mesh to which he had been reducing it. Let us probe only into the question as to whether, if prices were doubled, people would continue to use the same relative amounts of coal, steel, copper, lead and zinc, and only the gross value of those commodities would change. When we ask ourselves that question we see at once that coal and copper are not only competing with expenditures for food, clothing and housing for a due share of the expendible income of the hypothetical average family, but they are also competing with each other. The function of providing a roof over a family's head is one for which many mineral commodities (such as slate, tile, copper and zinc shingles and roofing, galvanized iron and "composition shingles") compete with one another. A general change in the price level would somewhat change the basis of competition.

A short time ago the American Construction Council published a chart analyzing the costs involved in a $10,000 building, which claimed to show that labor expenditures were $7,646 when all

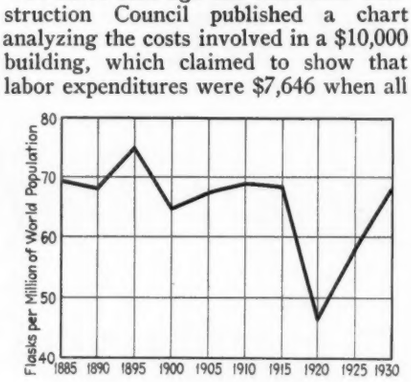

Fig. 1—Production of quicksilver in flasks per million of world population, 1885-1930. A mineral commodity the consumption of which has not increased

the labor involved in all the materials was taken into account. If wages are to be a larger proportion of the final sale price of every commodity, we shall not have a flat percentage change resulting from an increase in the general price level, because the ratio of labor to materials differs in alternative ways of doing things. For example, the materials in a plastered wall are cheap, but the labor involved is considerable. In a wall made of metal panels the material represents a much larger and labor a much smaller fraction of the finished cost. This one example illustrates the truth that a general rise in prices that does not change the ratio of prices of commodities does change their competitive basis. General Johnson was recently quoted in a magazine interview as saying, "The Administration will not monkey with the competitive picture unless there are evidences of monopoly and extortion." In attempting to manipulate the general price level the Administration is necessarily "monkeying with the competitive picture."

I do not mean to imply that the changes in competitive conditions that will necessarily result from manipulated price levels constitute a fatal defect in a policy of regulating prices. Competitive conditions are always changing, and industry is accustomed to adapting itself to them. It does not seem likely that one more cause of change will be the final straw that breaks the camel's back. But it should be foreseen that such changes will occur, even if we cannot forecast exactly what they will be.

Effect of Scrap

An important factor that must be taken into account in attempting to forecast mineral consumption is the salvage and reuse of used material. The word scrap is unfortunately applied both to old material and new; things that from the standpoint of economics are quite different. New scrap, like the remainders of dough left in cutting out cookies, is simply new material in unusable form and has only to be reworked into usable form. Sometimes it need not even be reworked; the scrap from making articles of copper is just as useful for brass-making as copper ingots, New scrap is part of our current supply of new materials, but old scrap is a competitor with new material for meeting human needs. Whether old material is saved and reused depends on how valuable it is and how much work is involved in putting it into form for reuse. It is easy to salvage the lead in a storage battery and not economically possible to salvage lead used in packaging tobacco. Though tin is ordinarily worth at least twenty times as much as iron, it is economically practicable to salvage heavy iron castings, but not practicable to save for reuse the tin foil of a cigarette or candy package. Practically all old gold (except that used in tooth fillings) is salvaged and reused; little of the tin of used tin cans is salvaged.

But after allowing for such well-known and complex relationships in the salvage of old material, one can see that the trend of recent years has been toward increased salvage, sometimes as a reaction to higher prices and in other cases because the trend of practice has been toward using materials in such large amounts as to facilitate salvage. That is complicated by a simultaneous trend toward lighter and stronger materials. This gives rise to such a specific question as to whether the amount of old iron coming back as scrap will, some time in the future, be sufficient, with the aid of strength-imparting alloying materials, to meet the requirements for new steel. Elaborate and careful studies of such specific problems have been made, and it would be useless to try to review them here, since even the most careful studies have been unable to clear up many points of uncertainty.

Will Mineral Consumption Increase?

The main query is whether the per capita consumption of mineral raw materials is likely to increase as much in the next fifty years as it has in the past fifty years. About the only thing we can be sure of about this is that, whatever the rate of growth is, it will differ for different commodities. World quicksilver production in 1930 was not more than 10 per cent larger than it was fifty years earlier, whereas world tin production in 1930 was 450 per cent of what it was in 1880. The increased use of detonators and the new uses found for quicksilver in the past half-century scarcely more than made up for the decline in its use in amalgamation and for other shrinking purposes. The uses of tin steadily grew, but how much more are they likely to grow? Will tin roofs hold their place? Tinware in kitchens has almost lost its place. Production of tin plate for food preservation has grown enormously. How long will it continue to grow? It is possible to argue that it

will hardly grow at all, so far as domestic consumption in the United States is concerned, inasmuch as students of demography of the Raymond Pearl school of thought believe that our population will not grow much in the next fifty years and will eventually become stationary. In that case an increase in the use of tin for food preservation will depend on a per capita increase in the use of preserved food. Will it increase? I do not know.

The birth rate in Europe is now reported to be only half what it was before 1900. No one knows what the rate of growth of world population will be, and it is equally difficult to guess whether the people who now make hardly any use of preserved foods will increase their use of them. More than half the people of the world live in Asia, and Willcox, who made a population study for the National Bureau of Economic Research, thinks the population of Asia has already become stationary. Who can foretell what the developments in Asiatic countries are likely to be, as regards their use of preserved foods.

My own guess is that the population of highly industrialized countries will not rapidly increase, and in countries like India and China it cannot increase much, so that our hope for increased mineral consumption, the world around, must be based chiefly on increased per capita consumption. When we look for data upon that, about all that can be found are the figures for per capita consumption, since 1912, for the United States, Germany, Great Britain, and France, that have been compiled by the American Bureau of Metal Statistics. Averages for three-year periods are presented in the accompanying table.

Interpretation

A glance at these figures reveals that they must be used with caution. The marked decline in 1919-21 in Europe may be interpreted as due to post-war dislocation of trade, absorption of the increased stocks created in wartime, and possibly to a lowered standard of living. Per capita consumption in the four countries in 1928-30 was approximately double that of 1919-21. In the United States this was also approximately double the 1912-14 level, but for the three European countries and the three metals, four figures are below the 1912-14 level and only one (lead in Great Britain) much exceeds it. That immediately raises the question as to how truly the 1928-30 figures for the United States represent an increased consumption, and how much they represent use in manufactured products sold abroad under the stimulus of foreign loans that now are in default. One fears to take some average figure of per capita consumption of minerals as representing a modern standard of living and then, by estimating that half the people of the world might be brought up to that standard, forecast a considerable growth in the consumption of these metals as soon as the present crisis is past.

The East as a Consumer

The great use of mineral raw materials in the four countries considered in the table, where 11½ per cent of the population of the world do 68 per cent of the total work of the world, and consumed, in 1929, 81 per cent of the world's copper, 74 per cent of the world's lead, and 76 per cent of the world's zinc, reflects their great use of mechanical energy, which in turn reflects a well-fed, energetic population. No doubt, if half the people of the world could be elevated even half-way to the standard of living of the most fortunate one-tenth, a great increase in mineral production and consumption would result, but I feel skeptical as to that possibility. Half the people of the world live in China and India, both lands of famine. The Chinese have been thousands of years making themselves what they are today, and after nearly thirty years of contact with them I feel very dubious that they will be much different in the near future. As regards the 40 per cent of the world's population that is neither in Asia nor in the four countries listed in the foregoing, and which consumed in 1929 15 per cent of the world's copper, 21 per cent of the world's lead, and 24 per cent of the world's zinc, it is impossible to generalize, for it includes such diverse regions as little Belgium, with a population less than that of the metropolitan area of New York City, and a zinc consumption, in 1929, of 36 lb. per capita (or over four times that in the United States), and the continent of Africa, with a zinc consumption of 0.03 lb. per capita. This indicates one of the statistical difficulties, for the Belgians surely do not "consume" so much zinc; they undoubtedly export it in manufactured form, rather than simply as slab metal. There are other difficulties; for example, the Bureau lists Russia as part of Europe, though about 30 per cent of its population is in Asia. Enough has been said, however, to indicate that a small fraction of the world's population uses nearly all of its annual output. We neither know whether the people who are using the most mineral per capita are near the limit of their consuming capacity (as they surely are in their consumption of food) or are still far from it, nor whether the people who now use very little mineral can be brought to use it in materially larger amounts at any time in the near future. It is perfectly clear that the per capita consumption of minerals *can* largely increase. My best guess is that as soon as the world recovers from the depression the per capita rate will again begin to increase, but at a somewhat slower rate than it has averaged over the past twenty-five years.

Yearly Per Capita Consumption of Metals

	Copper	Lead	Zinc
United States			
1912-14	8.09	9.01	6.42
1919-21	9.79	9.07	5.62
1928-30	16.01	11.03	8.87
Germany			
1912-14	7.01	7.26	7.70
1919-21	2.73	2.79	2.39
1928-30	7.43	6.72	6.65
Great Britain			
1912-14	7.25	9.35	8.72
1919-21	4.19	7.53	5.24
1928-30	7.20	12.55	8.66
France			
1912-14	5.33	5.20	4.08
1919-21	3.60	3.15	2.32
1928-30	6.97	6.27	6.52

It may be well to call attention to a mathematical error that sometimes creeps into discussions of the rate of growth of mineral consumption. Suppose the consumption of some commodity is tabulated and found to be a at the beginning of a period, $2a$ ten years later, $3a$ twenty years later, and $4a$ after thirty years. In thirty years the consumption has increased 300 per cent, but the statement, sometimes seen, that it increased 10 per cent *yearly* is incorrect. The actual curve of consumption is shown at A in Fig. 2; it is a straight line with the equation $y = 0.1\ ax + a$. A curve of consumption that increased 10 per cent yearly would be defined by the equation $y = (1.1a)^x$, and is shown at B in the figure. The consumption at the end of thirty years would be $17.49a$ on curve B, instead of the actual consumption $4a$, represented on curve A. At the end of 100 years consumption on curve A would be $11a$, and on curve B it would be $13780a$.

The point of this is that consumption curves cannot be of the kind conforming to an exponential equation. Consumption increases because (a) the consuming population increases and (b) each person consumes more. The world population does not increase by a yearly percentage; we have already reviewed the evidence that it is increasing only slowly and is perhaps already near its maximum. Individual consumption cannot increase by a percentage yearly; when it seems to do so it is only for brief periods (fifty years is a brief period in world history), after which the curve will flatten, or perhaps even turn downward. That is because many mineral substances are *used* but not consumed. A lead-covered cable of copper wires can go on transmitting messages indefinitely; only an increase in the population to be served or of the per capita messages they have to send will call for more of the metals.

Economic Nationalism

Another factor that must be thought of is the trend toward partitioning the world, through economic nationalism, into a series of trade-tight compartments. Like the bathing girl who was adjured to hang her clothes on a hickory limb but not go near the water, every country wants to sell in world trade but to preserve its domestic market for itself. The traditional way of attempting

to secure this paradoxical result was to impose import tariffs, but now artificial depreciation of the exchange rate has been developed as a supplementary mechanism. The yen has been manipulated down to 20c. from its par of 50c. with the result that a Japanese product that formerly had to be sold in our market for 25c. to meet manufacturing costs at home can be sold here for 10c. and still yield the same return, in yen, to the Japanese manufacturer. There is a catch in it, of course; if the manufacturer has to use any imported raw material his production costs show a corresponding increase in the cost of raw material, but his processing costs do not rise unless wages are allowed to rise. Japan's foreign trade for the first six months of 1933 showed a 53.3 increase over the corresponding period of 1932, while our foreign trade showed a decline of 20 per cent for the same periods.

Imports are discouraged and exports encouraged by a low exchange rate, providing wages and prices do not advance. There seems to be much doubt as to whether artificially depressed exchange rates can be long maintained, and whether the increase in exports which they undoubtedly produce represents any real gain, when the increased cost of imports is also taken into account. As a mechanism for stimulating exports and discouraging imports it is too new to be certain of what its effects will be. One must note, however, that it represents a reversal of the old basic theory of foreign trade, in which the aim was to trade the smallest possible amount of goods from home for the largest possible quantity of goods from abroad. If Japan buys cotton from India and sells India cotton cloth, the old idea was to trade less cloth for more cotton, whereas a low exchange rate of yen for rupees operates to trade more cloth for less cotton. The idea, of course, is to capture the Indian market for cloth, and raises the old question as to whether it is better to do a small business at a good profit or to do a big business at little profit. We cannot debate that question here, but it needs to be mentioned as a factor in the general problem under consideration.

Tariffs and Their Effect

Tariffs have taken on a new aspect, also. Originally they seem to have been regarded as temporary protection for "infant industries," something like the basket a gardener puts for a few days over a young plant after transplanting it. Our tariff on tin plate is a good example of that. Nowadays tariffs are more like a Chinese wall thrown around a country's boundaries as protection against raids from outside. If our shoe-manufacturing plants can supply the domestic demand for footwear, and foreign manufacturers start selling shoes in our market below the prevailing price level, it may be because the foreign manufacturer is (a) selling at a loss to capture part of our market, (b) is selling here at a low rate to keep his plant operating at full capacity without having to reduce prices in his own country, or (c) his manufacturing costs (either from improved technique or low wage rates) are actually lower than ours. If a new plant in this country was able to make and sell shoes cheaper than anybody else, the others would be expected to find some way of meeting that competition. Few people urge that the same rule apply to foreign competition, because it is hard to prove that imports are coming in on the (c) basis; they may be due to (b) or (a), or be none of the three, being due to exchange rates, discussed in the foregoing. The present trend seems to be toward preserving the home market for the home producer.

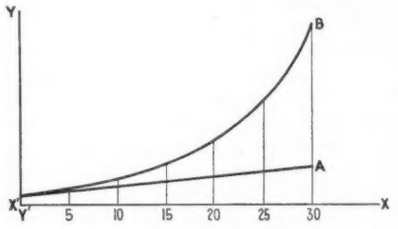

Fig. 2 — Curves illustrating growth of mineral consumption. Curve A, consumption increases 300 per cent in 30 years. Curve B, consumption increases 10 per cent yearly.

This is not the place to review the arguments for and against "protective" tariffs, especially since, although such a policy may be enacted into legislation, it is almost never on the basis of substantial agreement among all those concerned, but only represents the adherents of that view who are able to make their arguments prevail. Nor are we concerned with it here beyond making the point that if every country embarks on a policy of selling abroad but not buying abroad, in what markets are the sellers to sell, and with what are the buyers to pay for their purchases? The old Adam Smith idea was to trade what you could make cheaper than anybody else for what other people can make cheaper than you can. The new nationalism proposes to produce its own requirements, and still continue to sell its surplus abroad. How can it be done?

The greatest weakness of such a policy is that it cannot be a consistent one, as is well illustrated by minerals. No matter how fiercely nationalistic we should become, we could not meet our own needs for nickel or tin; a general nationalistic policy must be modified to facilitate their import, so that industries based on them may flourish. Nobody objects to such a modification. For years we had a large surplus of petroleum for export, and producers were so anxious to have a free market abroad that they were perfectly willing to allow one at home. But when times changed and they began to feel the effects of restrictions placed on our exports in foreign markets, as well as those of imports of crude into this country, counsel became divided. Should we facilitate the import of crude petroleum so that the refining industry, that depends on marketing a large part of its products abroad, can flourish? How could we consistently restrict the importation of crude of foreign origin and at the same time urge foreign governments to remove or lessen restrictions on imports of our refined products into their markets? Nationalism may be termed blind self-interest, because it is so hard to see how the interest of a country is best served. A policy that benefits one group is contrary to the interests of another, and it takes more than a certified public accountant to add up all the credits and debits and find a true balance. The balance usually attained is a political rather than an economic one.

One important aspect of this general problem is the question as to which country is to secure the social benefits of beneficiation processes. Concede that we have no usable tin ore in this country, and the obvious thing is to buy it in the cheapest market. But the countries that produce tin ore reply that they will not sell it; they will sell only the finished metal. Producers in this country would never have made much out of selling crude petroleum abroad; the profit was in marketing refined products. France, which cannot produce crude, is willing to buy it, but wants to set up a domestic refining industry. The final outcome for any specific mineral commodity is the resultant of a complex of technical, financial, and political forces, but the general rule is that a country that produces mineral wants to sell it in its mostly highly beneficiated, and therefore highest priced, form, while the country that buys wants to secure it in its crudest and cheapest form. There is no simple way to reconcile this basic conflict of interest between countries.

International Control

Whole books have been written about the international control of minerals without exhausting the subject, so it seems hopeless to try to discuss its future possibilities in a few paragraphs. One generalization, at least, seems possible —namely, that all forms of control tend to raise, not to lower, the price of mineral to the consumer, and therefore must, in a broad way, tend to curtail consumption. The actual effect depends on the competitive position, of course. Increasing the price of coal would curtail its consumption, unless oil and gas equally advanced, and a general advance would probably somewhat curtail consumption for all of them. But one doubts whether doubling the price of vanadium would have much effect on consumption, or whether we would use much more radium if it sold at half its present price. That the general effect of regulating and controlling trade in minerals is to increase the price to the

consumer, and that the general effect of increased price is a slowing of the rate of growth of consumption no one can deny, even though modification of these general rules is claimed for a specific case. World trade in minerals is increasingly being regulated and controlled, and the general effect of this control will be to apply the brakes, however gently, on the growth of mineral consumption.

J. R. Finlay's Opinion

Since writing the foregoing my attention has been called to the following statement made by J. R. Finlay before the Mining & Metallurgical Society on Jan. 18, 1933:

"In the consumption of pig iron, we have had complete saturation for near twenty years. Since 1920, in spite of the great boom that has intervened, the production of pig iron per capita has been 20 per cent lower than it was before the war. It took more than 100 years to come to this point, but it came. Similarly in fuels. I won't go into the details; I hope you will take my word for it: saturation is either here already or the curve of demand has flattened so much that its near approach is a practical certainty. This saturation is thus already established in products which amount to about three-quarters of the total mineral production; and for more than seven years the suspicion has been growing with me that iron and the fuels were just pointing out the road that other minerals must follow."

Why I think this a too pessimistic view to take has perhaps been sufficiently indicated above, but I introduce it here in case anyone may think me too pessimistic. Also, on Oct. 27, 1933, H. N. Eavenson, chairman of the Coal Division of the A.I.M.E., said: "Under foreseeable conditions it seems possible for this country to do a good year's business on a consumption of as low as 300 million tons of bituminous coal, and during the next ten years it is likely that a yearly consumption of over 400 million tons will be considered a large one."

The Answer Indefinite

To an engineer the most discouraging feature of an examination into the problem as to probable future growth of mineral consumption is that it results in no clear-cut and definite answers to the questions raised. The result reminds one of the treatment of malaria in the period before we learned that it was caused by a germ that was introduced into the system by a bite of a mosquito. People recommended the eating of garlic, sleeping in air-tight rooms, and a variety of other specifics that we now know could not produce the hoped-for result of preserving health. The business health of the world has been seriously affected, and one doubts whether the business doctors have any surer knowledge of cause and cure than the medical doctors had regarding malaria fifty years ago. In our own case we are not certain whether the high level of mineral consumption reached in the United States in the period 1926-29 represents an all-time high for us, or whether we shall soon recover the ground lost since 1929 and then again advance to progressively higher levels. The only thing we can be sure of is that we have not yet reached the limit of service that minerals can be to us; whether we will use more of them depends on economic and social conditions and the progress of invention, not the minerals themselves except in so far as we may find that less of a mineral can be made to yield the same service, as with coal, where 1 lb. now does the work done by 4 lb. twenty-five years ago.

We can be no more certain as to whether the people who now use but little per capita can be brought much nearer the rate prevailing in the five leading countries. The only thing that we can be sure of is that they would benefit if it could be done. Finally, no one can foresee what all the results of the recent rapid swing toward central regulation and control of nearly all human activities will be. We not only do not know how far it will go in this country, or what may be the results of what may be done, but there is not even general agreement on the results of what has already been done. Mineral production in Russia has for a number of years been under complete government ownership and control, and the pamphlets and books on the Russian social experiment would fill a twenty-five foot shelf. From reading them the only certainty deduced is that those who believe in socialism as a theory of society feel that the Russian experiment has been successful, while those who do not believe in socialism consider it a failure. Neither side can prove its contention, because no one can surely say what would have been the growth of Russian mineral production and consumption in the period 1917-34 if there had been no revolution. Since there is a difference of opinion as to the actual effects of past actions, what can we do but hope that some day our successors will attain a precise knowledge of the factors and forces in the functioning of society that we as yet admittedly lack?

? *Specifically . . .*

As to the Non-Ferrous Metals

Arthur Notman

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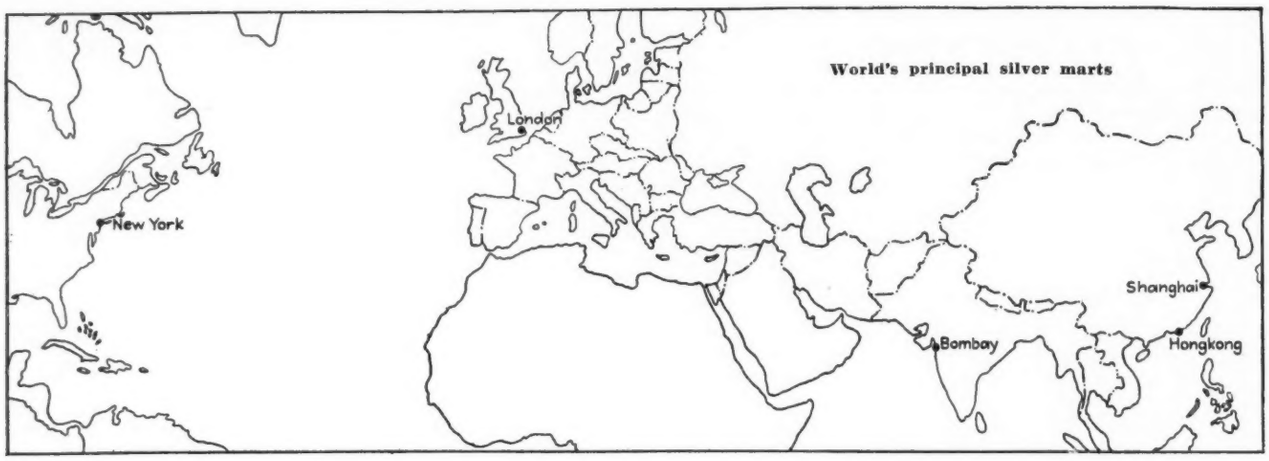
IN THE kaleidoscopic discussion of economic and monetary theories that surrounds us today, the natural-resource industries present an interesting contrast. All of this discussion revolves about the debt problem. How are we going to pay our debts? By deflation through the long, slow, grinding process of foreclosure, receivership, and bankruptcy, preserving the sanctity of contracts and the fifth amendment, or by inflation through their indirect violation or evasion. The industries we are concerned with either have debts that present no serious problems, or none at all. Yet they cannot escape the good or ill fortune that may betide because of the treatment prescribed for the country as a whole.

Pending decision and experiment with untried methods, the natural-resource industries with no debts, and the employees and communities dependent on them, can do little but wait patiently with profitless production or actual loss, until this debt problem has been solved.

The Race to the Swift

Patience, on the part of the owners, will not, however, put men back to work in our copper, lead, and zinc mines, mills, smelters, refineries, and fabricating plants. No codes can of themselves produce one consumer, but any codes which prevent the efficient from offering wares in the open market at the most attractive prices will kill off some of the remaining consumers. The race is to the swift, and the winner can in no



sense of the word be regarded as a "chiseler," if I have any proper understanding of that picturesque characterization.

In the natural desire of government and industry to protect those unemployed through no fault of their own, there is serious danger of heeding specious arguments. Those members of industry who are fully aware of their inability to stand on their own feet in fair competition, advance the sufferings of those dependent on them for jobs as a plea to have the government underwrite all their past mistakes and present weaknesses by allocating to them a share of the market which they cannot retain on their merits and to guarantee them against loss by fixing prices. To adopt such a policy as a means to reestablish stability of industry is probably the last word in futility.

The sooner such dangerous schemes are abandoned, and the problem of caring for and relocating the unnecessary employees is squarely faced by local, state, and federal authorities, the better for all concerned. It should be an occasion for rejoicing that the industry no longer needs so many people. In due course they will be free to fill many other unfilled wants of the community. To deny the benefits of improved technology is simply turning one's back on the progress of civilization, and will solve no problems.

Of the natural-resource industries those producing metals have a problem of their own. In greater or lesser degree, the metals are not consumed by use, and may be recovered for reuse. Conceivably some day, perhaps a far distant one, the world will find that the supply of junk metal above ground is ample to meet all its requirements for new structures. Individually, the metals differ substantially in this respect, depending on their resistance to wear and corrosion, and the forms in which they are used. Iron and ordinary carbon steels are easily corroded. Most of the zinc used in galvanizing and all that is used as pigment is gone forever. Similarly, lead used in the pigment industry is dissipated. Copper, on the other hand, is indestructible. Nickel and chromium have similar characteristics, but in the latter case a substantial portion used in the refractory and chemical industries is actually consumed. Aluminum metal is long-lived also.

Of the common non-ferrous metals, zinc is therefore in the most favored position, with lead next, and copper last.

In the minds of most of us there has been some reluctance to accept this factor of the relative indestructibility of the metals. It is an unpleasant fact, however, that must be faced. It is true, also, that in the case of the non-ferrous metals, substantially more than half of the new production is taken by the construction industries, and consumption, therefore, rises and falls with the activity of those industries. In this, as in all previous depressions, it is precisely there that the pressure of unemployment has been greatest, and is reflected in the subnormal demand for raw materials.

Price Policies

The only inducement that the metals have to offer to capital is low price. This is especially true in the case of copper, where the excessive inventories in the hands of both producers and fabricators is a major problem and competition with secondary metal is keenest. In their case, the mistaken price policies of the past if repeated will lead to disaster. Unwillingness to compete as evidenced by the recent successful bid of the Aluminum Company of America for the transmission lines required by the Tennessee Valley Authority is a symptom of senility that may betray the industry in its progress toward recovery. Fortunately for them, neither the lead nor the zinc industry has any serious inventory problem, and both are in a position to benefit promptly by any improvement in the construction industries.

The Public Works Administration is designed to prime the pump of construction activity in the country and start the heavy industries to work. But, unless it is careful to see that construction costs are kept low, there will be little incentive for private capital to take up the burden. The present surplus of office buildings, apartments, and hotels, and the condition of urban mortgages and real estate bonds, do not present any alluring prospect for profit in building more of the same unless they can be erected more cheaply than at any time since the war.

Hope is felt, however, that ways and means can be found to rebuild substantial portions of our cities into homes for the people of incomes below $5,000 inexpensively enough so that they can afford to live in them. The crux of that problem, as clearly stated recently in the *New York Times* of Dec. 1, 1933, by Dr. O. M. W. Sprague, is to find methods and materials that will make this possible, and at the same time pay fair wages and provide a satisfactory product that will be used profitably to both tenant and landlord. The metal industries are vitally concerned in such an undertaking and should shun price policies which might defeat it.

Whatever may happen in the future, the metal industries are materially better off than they were a year ago. For the long term, I believe they will prove to be nearly as profitable as in the past per unit of output. I say nearly, because we are no longer a pioneer country, and most of our big construction needs are filled. Future work will be remodeling rather than new building. Excess capacities that are inefficient will have to be eliminated, but the share of earnings that will be available for capital may be as large as in the past, because it will not be necessary or wise to put so much of them back into new facilities.

More than ever the prizes will go to those whose product is sound and whose costs and prices are low.

Outlook Favorable for Silver

But Danger Lies in a Sudden Price Advance

Ludwig Vogelstein

Chairman,
American Metal Company, Ltd.,
New York

SILVER has been the butt of economic controversies for over one hundred years. It has been dragged into the political arena time and again, but belief has been general that the second defeat of Bryan in 1900 ended the discussion forever in the United States. Extraordinary economic developments have brought the subject once more into the foreground, and, although the arguments pro and con are not new, few men retain an impartial position. Although I am trying to view the situation impartially, I am afraid some of my statements may be challenged by partisans of the various theories. I therefore approach the question with a certain hesitancy.

Prediction of the future always involves danger, but this is particularly true at the moment (the date of writing this is Nov. 27), in view of the uncertainty of the value of the dollar; furthermore, with respect to silver, all kinds of plans are being discussed—nationally in our country and internationally at the recent Economic Conference—which may have a decided influence on the price of the metal and the demand for it. How quickly the situation may change and how easily one may be misled become more evident to me after rereading two papers on the silver question which I had written this spring. In one of these papers I ventured the prediction that China and India would not jettison large quantities of silver even if the price advanced materially. A few months later, during our inflation boom, both countries dumped large quantities on our market, even though the gold value of silver advanced only slightly. The reason for this phenomenon is that Chinese exchange is based on silver and is dealt in daily in large amounts in Hongkong and Shanghai; a fact which we are too likely to forget. When our wild speculation on the Commodity Exchange drove silver above the parity of Chinese exchange, arbitrage transactions took place until the parity was re-established. In consequence of these arbitrage operations, silver moved from the Far East to New York, but the disparity disappeared so rapidly that by the time some of the shipments arrived in New York, it was profitable to return the silver

Ludwig Vogelstein

bullion and coins to China by the same steamer which brought them here.

A most interesting and valuable book on silver has been published recently by Y. S. Leong under the auspices of the Brookings Institution. While Mr. Leong is sound and logical in most of his statements and arguments, I have to disagree with him on the question of the possibility of a much larger silver production in case of a higher price for silver. My third point below is fully corroborated by Mr. Leong's investigation, but apparently Mr. Leong has not made as complete a study of the effect of price fluctuations on production of silver as I made when I presented a paper to the American Institute of Mining and Metallurgical Engineers last May.

Fundamental Facts

A careful analysis of the silver situation discloses the following fundamental facts which have to be understood clearly before we can discuss future possibilities.

1. Silver is an international article and its currency price in countries which are not on the gold basis fluctuates with foreign exchange quotations.
2. The gold value of an ounce of silver has fluctuated in the past parallel with the commodity index.
3. The production of silver at present from true silver mines amounts to about only half of the total, while about 50 per cent is produced as a byproduct by copper, lead, and zinc mines. (In 1929, about 40 per cent came from straight silver mines and about 60 per cent was byproduct silver.)
4. No large deposits of silver which could be operated even at higher prices are known.
5. Experience has taught us that high prices for silver do not stimulate its production, but a good demand and higher prices for copper, lead, and zinc do increase the output of the white metal.
6. Depreciation of currency in the silver-producing countries has not materially stimulated silver production in the respective countries, although it has reduced production cost.
7. The principal demand for silver is still for monetary or exchange purposes; industries and arts are a minor factor. Whether all the possibilities for the use of silver for industry and art have been thoroughly canvassed is doubtful.
8. Far Eastern countries—especially China and India—have hoarded silver for hundreds, possibly thousands, of years; enormous quantities which normally do not come on the market are stored in these countries, but in 1933 this silver did come on the market to the extent of over 100,000,000 oz., showing that we must not overlook its existence.
9. In spite of the large shipments from the Far East in 1933, the visible reserves in China are larger than before these shipments were made, and in India the decrease in the visible reserves reflects barely half of the amount shipped out. This proves the danger lurking in the large hidden reserves of Far Eastern countries.
10. Contrary to popular opinion, since the price of silver declined, exports to Far Eastern countries have been reduced less in volume and gold values than imports from Far Eastern countries; apparently the price of silver is not the decisive factor for the trade movement, but the demand for merchandise. The Far East has rarely, if ever, paid in silver for imports, but by exports of raw materials.
11. Silver is a splendid medium for speculation, especially for countries off the gold standard.

The world's silver production in 1933 will fall short of 160,000,000 oz., as compared with 169,000,000 oz. in 1932 and 262,000,000 oz. in 1929; the latter was the peak production. In consideration of the fact that even at the peak of the world's prosperity, only 60,000,000 oz. was used in the world outside of

China by industries and arts, and that most of the countries of the Western Hemisphere have bought very little, if any, silver for coinage during the last ten years, whereas some countries have sold their demonetized coins, it is certainly most surprising that the annual production has been more or less absorbed, even though in part by speculation, and that the price did not decline when the East dumped silver on our market. One may well question whether the London and New York silver markets could stand a repetition of such dumping operations. Our main hope for better prices for silver expressed in gold lies in the Far East, which, in the prosperous years of 1925 to 1929, absorbed on the average 180,000,000 oz. annually. The demand from the Far East depends largely on commodity prices. During the war England asked and obtained our assistance for payments of silver to India; we advanced them about 200,000,000 oz. because, at the high commodity prices prevailing and the large exports of commodities from India, the current silver production was inadequate for the settlement of trade balances. When commodity prices fell in 1920 and 1921, the demand for silver slackened simultaneously. Inasmuch as the world has been on the ascending curve of the business cycle for over a year, we have reason to look for an improvement of the silver market in gold values.

Promotive Efforts

In the meantime, efforts are being made in various directions to create additional demands for silver in the Western World. At the Economic Conference in London a plan was adopted, subject to ratification by the various governments, which compels certain Western countries to buy quantities of silver annually for monetary purposes and limits other countries, especially China and India, as to the quantities of silver which they may sell. Even if this plan be ratified, it is not likely to have a great and lasting effect on silver; first, because the quantity to be bought by the various governments is not very large—about 35,000,000 annually; second, the quantity allowed for export from India of 35,000,000 oz. is larger than her average exports for the last four years; third, we may doubt whether the restriction of exports of silver placed on the various governments can and will bind individual citizens; fourth, unless the Far Eastern demand for silver is restored to somewhat near the level of the last decade, the power to absorb current production and accumulated stocks does not exist.

Another plan has been proposed which, in my opinion, would be more sound and would possibly have a more enduring effect, provided, of course, that the Far East does not reverse its traditional preference for silver: The Western World can absorb a large additional amount of subsidiary silver coin. Germany has increased its silver coins during the last few years to Mk. 30 per capita, or about $7 in gold dollars. No definite information is available as to the outstanding subsidiary coins in various countries. In the United States, about $250,000,000 in silver subsidiary coins is issued and in circulation, equivalent to about 200,000,000 oz. of silver; in other words, about $2 per capita. To increase this coinage to $7 per capita would require 500,000,000 oz., and if other countries would follow suit, a demand for upwards to 2,000,000,000 oz. would develop. To facilitate the absorption of the new silver coins, it should be stipulated that central banks could count them as part of their metallic reserve, provided it did not exceed a certain maximum percentage of the reserve. Such large quantity would not be immediately available, but even if the purchase would be spread over ten or twenty years, the equilibrium of demand and supply would be assured for a long time if the Far East can be counted on to take silver in settlement of the invisible balances. The attitude of the Far East probably will be governed by the following:

1. An unreasonable or sudden advance in the price of silver is likely to unlock vaults where silver is hoarded.

2. An advance in commodity prices will increase the silver requirements of the Far East.

A number of other plans have been proposed, some of which have little or no chance of being adopted because they strike at the root of sound money standards; others are of such a character that they are not likely to have an important bearing on the silver market. It would lead too far to discuss them all. We, in the United States, have to be on guard lest this country be made the dumping ground for silver.

Speculation

A most important factor for the silver market is speculation. As already stated, the silver markets in the United States and in London fluctuate with the currency of the respective country. With the dollar at 100 per cent, we reached the all-time low at the end of 1932 of 24¼c.; by March 10, 1933, with the dollar still practically at par, we had advanced to 29¾c., owing to speculative buying caused by fear of depreciation of the dollar, and on April 8, before the gold embargo order was issued, the market had receded to 27c. When the dollar started to drop, the silver price advanced in United States currency, sometimes faster than the dollar's decline, and in such moments our market became the target for China's and India's dumping. Theoretically, if the dollar drops to 50 per cent and all other market conditions remain stationary, silver should sell in New York at twice the gold price. At this writing, it is selling in New York at 44.63c., while the dollar is quoted internationally at 62 per cent. This means that the gold price of silver is 27.67c., or practically the same as it was before our currency was depreciated.

A Danger

In my opinion, the outlook for silver is favorable and much better than during the last few years. The improvement in world trade is bound to help silver. Production has been reduced by 40 per cent and will not increase quickly. The various efforts of interested governments to lift the price may prove successful, but the gravest danger to the market is a precipitate and sharp rise in price, for whatever reason it may occur. This would result in releasing hoarded silver in the Far East and is bound to have a deflationary effect in China which will probably upset business in the Far East. A gradual rise parallel to an advance in commodity prices is more desirable and would be viewed, particularly by the Chinese and Indian people, as a sign of returning prosperity.

Mr. James Warburg, in his recent letter to Senator Borah, stated the case correctly, in my opinion, when he wrote:

"I do not go so far as to say that doubling the price of silver will double the purchasing power of the Chinese, because I believe that the purchasing power of the Chinese depends in the last analysis upon the goods and services that China can export. I do not know what level for silver is best for the development of the Chinese economy, but I do know that it cannot be good for the Chinese economy to have excessive fluctuations in the gold price of silver."

And Mr. Leong, whose book I mentioned in the foregoing, points out in his summarizing remarks:

"The reduction in the price of silver has none of the alleged cataclysmal effects of depreciating the purchasing power of India and China in foreign markets."

Mr. Leong is rather optimistic on silver on account of the statistical position as he sees it, but I think he underestimates the possibility of exports from the Far East.

Conclusion

Assuming an early stabilization of the dollar and pound sterling, and barring war or other serious political disturbances, I believe the world is gradually working out of the depression. Commodity prices will advance in gold with a return of confidence. Silver will either lead or follow the advance of commodity prices in gold, but it will not stay behind the procession unless artificially held back by powerful governments. This is not to be expected; to the contrary, in the process of stabilization of currencies, hard money is likely to play an important rôle and to be in good demand for coinage purposes.

The Future of Secondary Metals

As Viewed by An Optimist

Their Rôle Important

J. W. Furness

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IN THE PAST, in times of plenty, little thought was given to the prevention and avoidance of waste; but as our complicated industrial evolution has progressively developed, competition of one industry with another has grown more and more keen. The problem is no longer "How can we obtain a quantity of this or that mineral?"; it has become, rather, "At what price can we supply our so-called needs?"

In the United States, up to recent times, consumers found it far cheaper to buy new metals rather than to renovate the old. Before the construction of our intricate system of highways, thus providing cheap transportation, relatively large amounts of metals—for example, iron and steel in the form of farm equipment—were dissipated annually because reclaiming was not feasible. But today, with an estimated steel production of 50,000,000 tons, more than half of the iron requirement comes from salvaged material.

The development of the secondary-metal industry came first through the simple desire for a scrap trader's profit. It was encouraged by better organization of the trade. Then entered importantly the influence of the metal user who had come to realize that old metal had a real value, which on sale could contribute a significant amount to reduce the net cost to him of new, enlarged, or improved metal parts replacing the old, worn, obsolete or inadequate ones. Finally the fact became clear to the metal producer that he too must support the system for reclaiming, lest otherwise he be excluded from much of the market for his products by others supplying secondary instead of virgin metal. Thus a mutuality of interest has developed and a sound basis is furnished for both permanence and growth of the secondary-metal industry.

The United States is the only one of the industrial nations compiling comprehensive figures on the secondary metal recovered. For this reason world comparisons based upon facts cannot be made; but by inference certain conclusions may be drawn. The pressure of need has not been as great in the United States as in Continental Europe or the Far East. For this reason salvaging of waste has probably not reached as high a degree of efficiency in the United States as in the older countries. Almost without exception, in the industrial countries depending largely upon imports for their requirements of some of the essential metals, prohibitive export duties are laid on scrap, the attempt being made to conserve these metals as much as possible.

Utilization

In the past, broadly speaking, little thought has been given to the utilization of metals from the standpoint of their conservation. Consumers and fabricators have used a metal as best suited their convenience without ever a thought of the future. But notwithstanding this seemingly thoughtless method of utilizing material which is irreplaceable, certain qualities of metals have rendered them difficult to destroy totally. This may be considered by some as fortunate; by others, unfortunate. No one can look far enough into the future to prophesy with safety whether this, that, or the other metal will continue to be used in those applications for which the respective metals are now preferred. A school of pseudo-economists believes that what is at hand should be used without thought of the future; the opposite school holds that as the existing social structure is in great degree built upon the utilization of metals (and metals are, broadly speaking, ephemeral), care should be exercised in their utilization. A conservative middle group recognizes that inasmuch as conservation consists largely in the judicious utilization of a material, studies should be made for the elimination of such uses as give to man only a limited service, and these uses, wherever possible, should be satisfied by other substances of replaceable or inexhaustible supply.

Experience of the immediate past in the United States, together with the readjustment of social conditions which invariably follows times of depression, is likely to accelerate rather than retard the secondary-metal industries. The present importance of the secondary-metal business in the industrial life of the United States may be in part evaluated by the fact that the president of the National Association of Waste Material Dealers, Inc., George Birkenstein, has stated that more than 250,000 persons are engaged in the salvaging of waste in the United States.

Increasing Prestige

Of necessity the actual gathering by the scrap collector reaches to the humblest strata of our society. But industrial reclaiming has grown rapidly. Until lately the re-melting or re-processing of the reclaimed material has been an industry unto itself. Now, however, the secondary-metal business has passed from the period of infancy into one of real technologic advancement.

If all interested in this important subject consider the fact that not so many years ago the exalted profession of "the doctor" was looked upon, to say the least, in a very patronizing way, that doctors were classed with barbers, and that in England they were required to use the tradesman's entrance, and if note be taken of the awe with which a prospective patient now approaches the successful doctor's office, the great advance of this profession in our social scale will be realized. Not so many years ago one would have had to search far afield to find an iron metallurgist who had any metallurgical education other than that of the empirical school of experience. But now primary metallurgy has a dignified status. That secondary metallurgy will follow is a warrantable conclusion. Thus will economic evolution professionalize the salvage industry.

With the ever-increasing volume of material, secondary metals have played a larger and larger part in the influencing of the price at which primary material may be sold. In times of depression secondary metals, due to price, evidently constitute in many applications the larger part of the consumption. As

an example, in 1932 secondary lead constituted 69 per cent of the primary metal produced. The copper-scrap industry will presumably follow the same course.

If secondary metal be compared with primary, the fact is developed that competition is on a very unequal basis, in that secondary metals have already been reduced from their ore and are in a highly concentrated form. The fact that the gathering or salvaging of metals is far less expensive, unit per unit, than the actual mining of a tonnage of ore sufficient to produce the equivalent in metal, makes it evident that, from the standpoint of price, secondary metal can almost always have a price advantage in the consuming market. In many, perhaps most, cases there is no chemical difference between secondary material and primary. The disadvantage in the cost of production is one that the primary producer cannot overcome by quality claims. He may actually be forced to enter the secondary industry himself.

A Problem

With the greater utilization of alloys during the past twenty years, the problem of the utilization of scrap in the steel industry becomes more acute. Informed authority has stated that scarcely a ton of steel of today's manufacture is free from copper. Scientific sorting of scrap will come more and more into vogue as a necessity, and accompanying this will be a greater and greater demand for control by the chemist and metallurgist. Here is a compelling factor in the professionalization already mentioned.

In the utilization of metals some services do not destroy the metal during use; but others dissipate it. These are the points which in the immediate future will no doubt be given more and more consideration. Already sales efforts give greater stress to uses that do not permit reclaiming of the metal or in which recovery for reuse can occur only after a long time. More care will be given also to the thought that comparative chemical characteristics of this, that, or the other metal must be given more consideration. Take, for example, in the utilization of iron: the oxide of iron ore constitutes by far the larger part of the raw material used. Broadly, with the exception of meteorites, iron does not occur free in nature. Man converts the oxide into metallic form in order to serve his purposes. Owing to the chemical affinity that iron has for oxygen, no sooner is the material formed than natural causes start to convert it back to the oxide. Weather-proofing and other such devices must be used. Certain metals added to steel, such as nickel, molybdenum, and chrome, retard, if they do not entirely prevent, oxidation, and therefore dissipation. The prolonging of the usable life of steel, as has been practiced in the last twenty-five years, must ultimately have a decided effect upon the primary production of iron ores. Such effects are already noticeable in long life in some iron uses. And recycling of alloyed steel may give this longer life to all metal even when not altogether intended by the producer of the product containing secondary metal.

Changes in Prospect

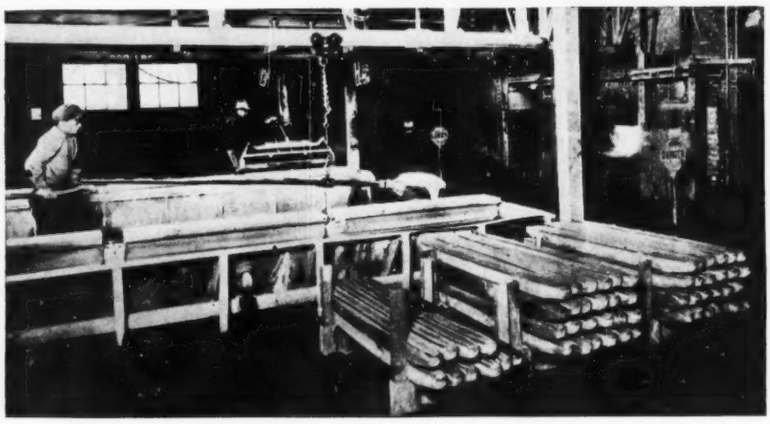
With the ever-increasing use of non-rusting, non-erosive steels, can anyone doubt that in a comparatively short time the curve indicating the consumption of virgin steel will flatten out? Broadly, will not society always be able to promote efficiency and economy by utilizing a highly concentrated metal or mineral rather than to extract it from its ores where the tenor may be as low as a few pounds to the ton of material handled? One may easily, without too much of a stretch of the imagination, accept the thought that in the immediate future probably as many radical changes in building construction will be initiated as have been evolved and approved during the last forty years. Will not the skyline, possibly even of such cities as New York, undergo many more radical changes during the next fifty years? And, if so, will not the obsolescence of the present architectural vogue release large tonnages of metals which are now in use? And if the effective life of a metal is increased by the use of this, that, or another material in order to alloy it, does not this longer life of the metal mean also that more of it will be salvaged and reused, due not only to practicability of recovery but also to lower cost of reclaiming and re-forming or re-melting as compared with the cost of obtaining new material.

Need for transportation occasions a major group of uses for metals, both ferrous and non-ferrous. In railroad development a trend is now evident which will be a large factor in determining tomorrow's usage of metals. Numerous seemingly effective efforts have been made in the production of extremely light-weight transportation units by use either of light aluminum alloys or of alloy steels, much lighter than customary rail-construction materials, or in combinations of the two types of metal. The availability of strong alloys for extremely light-weight diesel-engine building has been a significant aid here. High-speed rail transportation of passengers, mail, and express seems certain to result from these efforts, which is the partial answer to competition by airplane.

This group of developments will have several important consequences not yet generally appreciated:

1. It may put an end to the electrification trend because of the greater capital economy.

2. It is likely largely to affect power development plans, accentuating the trend to liquid fuels.



Casting copper wirebars at a Mid-Western secondary plant

3. It may even give an unexpectedly sudden return of copper by re-cycling from obsolete lines through the secondary-metal channels.

In industrial uses other than transportation equipment, rapid development of alloy steels and aluminum alloys is to be expected. And as this progress is accomplished, a reduction will come inevitably in the demand for galvanized metal, for brass, bronze, and copper, and even for some of the electroplated materials which formerly were required to secure adequate resistance to atmospheric action. As this effect becomes accelerated in the field of galvanizing, the largest single use of zinc will then be lost. Furthermore, zinc will lose in this market the only major use from which no re-cycling and reclaiming as secondary metal occurs, inasmuch as zinc used in galvanizing is all dissipated before reclaiming of the base metal occurs.

Metals That Last

One may fairly assume that gold used prior to the time of Ur of the Chaldeans may now be in circulation or more probably in the vaults of the United States or France. Even some "base" metals rarely disappear. That

the slogan under which producers have sold copper for years—namely, "the everlasting metal"—may ultimately prove the downfall of its primary producer seems a bit of satirical humor. With the exception of a relatively small amount of copper used in the chemical industry, an increment is added each year to the copper already in use. The amount now above ground may well equal all known virgin reserves. Substantially all of it will re-cycle many times, perhaps almost indefinitely, before being lost to civilization.

Any forecast of the utilization of metals should take into consideration the keen competition in the consuming market of one metal with another. This often plays a greater part in restricting virgin consumption of a specific metal than development does in increased consumption for new uses. The layman or the user gives little thought save to price in selecting the specific metal he is using. It is the mere accomplishment of his desire or aims that carries greatest weight. To most persons the fact that lead, for example, is used for a particular purpose causes them to believe that lead must necessarily be used for that purpose. However, from the most casual study of the consumption of metals, the fact becomes evident that the amount of metal required to satisfy demands varies greatly with price. Many national metal monopolies, as well as international cartels, have failed ultimately not only because a high price brings out uncontrolled competitive production, but also because a large part of the market that may have been enjoyed is lost through the substitution of a cheaper metal for the one then in use, due solely to favorable price. These factors may have a decided bearing upon the amount of a material that is salvaged or reclaimed and thus may control the source of the raw material, whether virgin or secondary.

Uses That Destroy

When the advances in metallurgy which have taken place in the last few years are considered, and students of the subject envision for a moment the restless, never-ending research going on to place a material on the market just as good as, or better than, something that is already being used, the fact becomes evident that in the immediate future more and more will research be expended upon the elimination of what might be termed the ephemeral uses of minerals. By this term is meant, of course, uses which give to man a very limited service, which might, other things being equal, be readily replaced by some other more abundant or reproducible substance.

For example, consider one competitive use of magnesium and chromium. Is it proper conservation to use for a refractory a metal with such qualities as those of chromium? Chromium brick is used in the open hearth in the manufacture of steel, due not to its superiority from the standpoint of resisting heat, erosion, and corrosion, but to the price factor. It is not as good as magnesia brick; but being so much cheaper it may be replaced one and one-half times as often as magnesia brick and the outlay of money be the same. Can industry continue indefinitely to dissipate chromium, a metal of comparatively limited resource reserves, and not use magnesium, which is so abundant?

So far as is known, alloys of iron containing a high percentage of chromium and nickel are indestructible. Therefore, regardless of the form, when present uses become obsolete, the chromium *at a price* will be available through reclamation for further service to man. Thus, just as in gold and in copper, an increment will be added annually by alloy uses to the amount of chromium in use, available for recycling. This result is in striking contrast with that which comes from use in refractories.

Estimated Use of Copper In the United States

American Bureau of Metal Statistics

Purpose	1932 Tons of 2,000 Lb.
Electrical manufactures *(a)*	90,000
Telephones and telegraphs	27,000
Light and power lines *(b)*	41,000
Wire cloth	4,200
Other wire	30,000
Ammunition	3,900
Automobiles *(c)*	32,300
Buildings	29,000
Castings, n.e.s. *(d)*	27,000
Clocks and watches	1,500
Coinage	100
Copper-bearing steel	800
Fire-fighting apparatus	1,000
Radiators, heating	1,000
Radio receiving sets	7,000
Railway equipment	700
Refrigerators	9,000
Shipbuilding	2,100
Washing machines	1,500
Water heaters, household	1,000
Other uses	27,300
Manufactures for export	22,600
Total	360,000
Use in pounds per person	5.77
Shipments by refineries	335,965

(a) Generators, motors, electric locomotives, switchboards, light bulbs, and related electrical goods. *(b)* Transmission and distribution wire and busbars. *(c)* Does not include starter, generator, and ignition equipment. *(d)* Bearings, bushings, lubricators, valves, and fittings.

Use of Lead In the United States *(a)*

American Bureau of Metal Statistics

Purpose	1932 Tons of 2,000 Lb.
White lead	54,500
Red lead and litharge *(b)*	15,800
Storage batteries	138,000
Cable covering	55,000
Building *(c)*	22,000
Automobiles	3,500
Railway equipment	300
Shipbuilding	200
Ammunition	23,300
Terne plate	1,400
Foil	14,000
Bearing metal	10,000
Solder	14,000
Type metal	10,800
Calking	10,000
Castings	5,000
Other uses	22,200
Total	400,000

(a) Includes antimonial lead. *(b)* Exclusive of oxides for storage batteries. *(c)* Under the head of building is included the lead used in chemical construction.

A Question

What will be the effect in the future on the mining of a virgin metal as the supply in use is augmented, ready to be released by technological advance and obsolescence of uses? Will the rate of the increase in consumption of the metal be sufficient to maintain the present rate of production of virgin material? These are now important questions, especially for non-ferrous metals. An answer to them, for illustration of general trends, may be found in some degree in the example of lead used for battery grids. The rapid expansion of the automobile industry from 1921 to 1929 greatly augmented the demand for lead for battery purposes. In 1925 the price of lead reached the highest peace-time point that it had attained in the last fifty years. There was talk of a shortage of lead from a world standpoint. Little consideration was given to the fact that only a small amount of the lead used for battery plates is lost. It has been estimated that 95 per cent of the tonnage so used is recovered; and that the life of a battery plate is only from eighteen to thirty months. As the volume of secondary lead increased, the effect upon demand of primary metal became evident. In 1928, 49 per cent of the lead used in the battery industry was of secondary origin. This ratio decreased slightly during 1929 and 1930, but in 1931 it was increased to 60 per cent, and in 1932 skyrocketed to 73 per cent.

If planning of industry becomes part of the social life of the nation, industry may operate on a more even keel. Then the great peaks and valleys of demand for lead will not disturb either production or marketing. And presumably the diversion of lead from the channel in which it flows to supply certain demands will not occur; it will instead merely re-cycle from old battery back again in a new one.

Secondary Reservoir Fluctuates

During the period 1929-1932, with the falling off of the demand for automobiles and the obsolescence of cars, more and more battery lead came on the market. The supply exceeded the automotive needs; and to realize on this battery, or hard antimonial, lead, it was refurnaced to be utilized as soft lead. Thus the primary producer lost not only his battery market but also some others which drew from reserves of battery secondary supplies. There can be no question that with the increase in the manufacture of automobiles, as indi-

cated by the last six months of 1933, virgin lead again will be called upon to supply what is now a basic need. The secondary reservoir which has been exhausted by the period of depression will have to be re-supplied by virgin material. But when this supply has reached a certain point, once again the demand for virgin lead will taper off, and secondary play its normal part. One notes here, between periods of "normal" use, intervals first of augmented difficulty and then of excess demand on virgin supplies, all being accentuated by secondary-metal supply.

Indications point to the fact that in the near future the metallurgist, chemist, and inventor will devote more time to the elimination of ephemeral, or annihilative, uses of metals, replacing these uses by synthetic organic materials or by other abundant substances. To be truly visionary, one may imagine copper used for chemical purposes, mercury used as an insecticide, lead used as a pigment, zinc used for galvanizing, and other applications of metals and minerals that involve their ultimate destruction, all eliminated by substitution; and many of these metals may be utilized in new industries such as air conditioning, which seems to be in its infancy. The future uses of metals may well then be confined to only those uses wherein the loss will be by abrasive action or in inevitable re-processing operations.

Control of Tin

From the humble gatherer of waste materials to an international governmental conference is a startling social metamorphosis. Nevertheless, the present situation in the tin industry will no doubt be greatly influenced by this "forgotten man." The largest consuming use of tin is in the manufacture of tin plate. In the processing of this commodity a comparatively larger amount of tin is always required within the factory than the amount of tin leaving the factory as tin plate. In other words, a working reservoir of tin is necessary in order to meet the output of the factory. As the output of the factory varies, so does the tonnage of tin required. In any recession of business little tin need be purchased by a factory, as it may be able to operate for some time on the tin which was in process. Later, as times improve, an apparent increased demand for tin will develop, a part of which does not find its way for some time into actual use. In times of depression invariably the ratio between recovered tin and virgin in consumption varies, and secondary supplies an ever-increasing quantity to the current demand. All these changes, of course, most affect virgin producers.

During the past year the international cartel in tin has been able to reduce the visible supply of tin materially, and the price in the last two years has increased from 33½c. to 55c. a pound. Imports into the United States during the past eight months have been what might be termed normal. Tin-plate mills have been running at near capacity, indicating that the market for containers, due to the depression, was devoid of stocks and that the replacing of these stocks has in part increased the apparent rather than real consumption. Inasmuch as the imports have been normal, a larger tonnage of secondary will evidently be available in the year 1934, and as the price is high the assumption that secondary tin in 1934 will play an important part in the future price structure becomes reasonable. The price of tin as it now stands may well be entirely out of ratio with the price of other metals, and this condition may invite substitution in many of the uses of tin, and as the secondary metal comes increasingly into use in preference to primary, notwithstanding all the plans of the international cartel, the price will break. The responsible party will be, as has been mentioned, the humble gatherer of waste materials.

Estimated Manufacture of Zinc In the United States

American Bureau of Metal Statistics

Purpose	1932 Tons of 2,000 Lb.
Galvanizing (total)	109,000
Sheets	52,500
Tubes	16,000
Wire	12,100
Wire cloth	4,400
Shapes *(a)*	24,000
Brass making *(c)*	66,000
Rolled zinc	48,000
Die castings	17,000
Other purposes *(b)*	27,000
Total	267,000

(a) Includes pole-line hardware, hollow ware, chains, and all articles not elsewhere mentioned. The estimates for the use of slab zinc under this head, and also for wire cloth, are probably incomplete. *(b)* Includes slab zinc used for the manufacture of French oxide, lithopone, atomized zinc dust, die castings, wire, zinc for wet batteries, slush castings, and for the desilverization of lead. *(c)* Includes all casting other than die casting, slush casting, and battery zinc.

Proportion of Secondary Metals Recovered As Compared With Primary Output,[1] 1918-32

Year	Aluminum %	Copper %	Lead %	Tin %	Zinc %
1918	26	37	17	29	23
1919	29	44	24	42	23
1920	23	51	25	28	25
1921	33	86	25	40	39
1922	44	71	33	25	39
1923	33	57	34	36	27
1924	36	47	34	43	23
1925	59	50	35	36	22
1926	57	55	41	39	23
1927	58	58	35	46	24
1928	46	59	40	41	25
1929	43	63	40	35	23
1930	34	67	40	29	20
1931	34	67	53	27	25
1932	46	91	69	38	23

[1]Dunlop, J. P.: "Non-ferrous Secondary Metals Recovered in the United States." T. P. No. 97, A.I.M.E. 1928. Also "Mineral Resources of the United States," annual chapters.

The secondary-metal industry, though an age-old occupation for man, is but in the dawn of its development. Scientific methods applied to the industry, and care exercised in the utilization of metals from the standpoint of life of service, will no doubt give to man for many generations material to meet his demands. Just as the theory of Malthus of a few years ago, which predicted the population of the world starving, due to the increase in birth rate over the death rate and to limited agricultural land from which man could derive his food, proved to be without validity, the cry of "Wolf!" in reference to the exhaustion of our metals is a concern of the distant future and need not, with the incidence of scientific conservation, give the user of metals any present anxiety.

An Analogy

All interested should note an analogy outside the metal field as a convincing proof. Who would have believed that, with an abnormal excess amounting to millions of barrels of oil, reclamation of oil products would be practiced? Yet there is a plant in Seattle where crankcase oil from automobiles is reprocessed, brought up to standard analysis and specifications, and re-sold as a subbrand. This plant is operated by joint ownership, and lubricants of various oil companies are shipped to it; credit according to weight is given to the company shipping; and a service charge for renovating the oil is made. The revived lubricant is actually delivered to the original shipper. Secondary-mineral operations clearly do not depend on shortages of virgin supply!

Notwithstanding the fact that the primary copper producers, as well as other metal producers, would welcome a dissipating, or destructive, use, provided it was of sufficient magnitude actually to curtail the amount of copper subject to reclamation, the inventor, metallurgist, and chemist will more than offset any such tendency by assisting in the avoidance of such uses and thus prolonging the useful life of the materials on which our present-day civilization is based.

The proportion of secondary aluminum, copper, lead, tin, and zinc recovered in the United States, compared with primary production, 1918-1932 inclusive, was approximately as given in the accompanying table.[1] The percentages given in this table are the ratio between primary domestic production as compared with secondary recovery, and do not represent the ratio between consumption and secondary recovery. This, of course, does not apply to tin, the ratio in this item being that which exists between imports of tin and domestic reclaimed metal.

Obviously, if the amount of secondary material indicated were not available, just that much more primary material would be required to satisfy the uses through which the metal flows. As an example, in 1932 secondary copper represented 91 per cent of the smelter production from domestic ores. If this copper had not been available, broadly 1,000,000 tons of virgin material would have been required in 1932 to meet the requirements of the copper industry.

Theory Trend as to Ore Genesis

The Probable Course of Events in the Light of Physico-Chemical Knowledge

Clarence S. Ross

Geologist, U. S. Geological Survey

ORE GEOLOGISTS and mining engineers have long recognized the need for a knowledge of ore-forming processes, and this factor will have an increasing importance, because mining must come more and more to rely upon concealed ore supplies difficult to discover; and the question of persistence in depth arises, with increasing demands for its answer. Many factors are concerned in these problems, among them structural control, relation to depth, and relation to various types of rocks, but none of these are of greater importance or of more absorbing interest than the processes by which the materials of an orebody have been segregated, transported, and deposited. Lindgren[1] has said: "Each deposit should be considered as a problem in physical chemistry, and the solution of this problem, with the necessary data, will suffice to fix the mode of formation of the deposit."

Ore deposits are of many types and have been formed by various processes, but a large proportion of them are generally believed to be derived more or less directly from a cooling and crystallizing magma. Formation of such a deposit is thus a part of the larger story of the differentiation of igneous magmas. Students of igneous rocks have turned from the problem of rock classification to that of differentiation processes. Experimental studies of igneous rocks began with anhydrous melts analogous to the strictly pyrogenic stages of differentiation; but water, other volatile materials, and the rarer constituents concentrated with these could not long be ignored and are today receiving increasing consideration. At the same time, students of ore deposits have been making increasing use of physical chemistry in interpreting ore deposition.

Field observations and experiments are beginning to give a connected story of the physico-chemical processes controlling the segregation, transportation, and deposition of ore materials and their associated gangue materials. The object of this paper is to present, in the light of our present physico-chemical knowledge, what appears to be the most probable course of events in the development of a typical orebody derived from an igneous magma.

Clarence S. Ross

Pyrogenic Stages of Differentiation—That the concentration of metals and other constituents representing a very small part of the primary magma had its beginning in the pyrogenic stages of crystallization is generally recognized. The concentration processes are commonly believed to be crystallization differentiation; that is, divergencies in the composition of the crystalline, liquid, and gaseous phases, as crystallization proceeded.

The pyrogenic stages of the crystallization of a normal igneous rock are characterized by the early formation of ferromagnesian minerals, followed by lime-soda feldspars, potash feldspar, and lastly by quartz, if the rock is sufficiently silicic. Due to temperature and other changes, some minerals react with the remaining magma and are changed to others; thus olivine is changed to pyroxenes, and then to amphiboles or biotite; and the lime feldspars are changed to more sodic ones. Such a reaction series tends to concentrate potash feldspar and quartz-forming material in the late residuum. The only stable minerals of igneous rocks that can fix the alkalies in important amounts are the aluminum silicates, most commonly feldspars and micas. If alumina is even slightly deficient in proportion to alkalies in the magmas, or has been previously removed as aluminous pyroxenes or amphiboles, enough may not remain in the residual portion to combine with all the alkalies present, and so part of these will pass into the residuum.

Most of the important igneous rock forming minerals, the olivines, pyroxenes, feldspars, and quartz, are anhydrous; and their crystallization tends to concentrate water and other volatile constituents in the magma residuum. This concentration of water has the effect of building up vapor pressures in the residual portion of the magma, as has been pointed out by Morey[2] and Bowen[3]. The tendency for the concentration of alkalies in association with an excess of SiO_2, and the ready hydrolysis of earlier formed silicates in the presence of hot water, insure a neutral or slightly alkaline residual material and preclude an acid character.[4]

At or near the end of the pyrogenic stage the residual magma will normally have become enriched in silica and alkalies, a marked concentration of water and other volatile constituents will have taken place, and it may be under relatively high vapor pressure. Certain rare constituents of the magma may also have been concentrated in this residual portion.

The pyrogenic stages of crystallization are followed by ones dominated by the presence of water and other volatile constituents, although no sharp transition from one to the other occurs. The new type of reactions may continue within the crystallizing magma; that is, be deuteric in character, or the residual material may escape and set up various types of reactions in new situations.

Deuteric Processes—The secondary reactions between crystals and residual

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[1]Lindgren, Waldemar: "Mineral Deposits," 3d edition, p. 231, 1928.

[2]Morey, G. W.: "Relation of Crystallization to the Water Content, and Vapor Pressure of Water in a Cooling Magma." *Jour. Geology*, Vol. 32, pp. 291-295, 1924.

[3]Bowen, N. L.: "The Evolution of the Igneous Rocks." Princeton Univ. Press, 1928.

[4]The term "acid" is here used to describe a chemically acid condition and not to describe the presence of an excess of silica, a usage which is not chemically accurate. Silicic is a better term than acid where excess silica is implied.

materials have a distinct relation to the reactions of escaping materials, inasmuch as these are initially identical. A number of widely occurring mineral reactions show the presence in quantity of certain elements in the residuum. Albitization of lime-soda and potash feldspars shows the presence of sodium; the formation of micas at the expense of plagioclase, the presence of potassium; and the formation of alkalic feldspar-quartz intergrowths by replacement, the presence of alkalies and silica. The formation of hydrous minerals, such as the micas, amphiboles, and epidotes, shows that water was in higher concentration than in the earlier pyrogenic stages when these minerals were not stable. There is also evidence of the concentration of some of the less common elements in the late residuum of many igneous rocks. Finely disseminated sulphides, as in the Duluth gabbro and Keweenawan flows, show the presence of sulphur combined with iron and copper. Carbonates replacing ferromagnesian minerals are not rare in igneous rocks and show the presence of CO_2. Other minor elements are indicated by the presence of boron in tourmalines, fluorine in micas and apatite, and phosphorus in apatite.

Effect of Instability

Some of the widespread changes observable in igneous rocks are due to the instability of certain minerals in the presence of water. Thus, the pyroxenes tend to alter to amphiboles, to epidote, or to chlorite. The anorthite molecule of lime-soda feldspars is unstable in the presence of water and tends to alter to muscovite or zoisite. On the other hand, the albite molecule is highly stable under these conditions. The instability due to the presence of volatile materials results in general only in the minor addition of materials and not in the breakdown and removal of these minerals.

The residual materials may escape from the parent rock at any stage in the crystallization process through filter-press action or the pressure of concentrated vapors. If this occurs after the concentration of feldspar and quartz-forming materials, aplites or pegmatites will be formed; and at still later stages hydrothermal deposits of various types.

Many pegmatites have been modified and new minerals introduced by post-magmatic hydrothermal replacements. Most of these minerals are of a type that show no obvious relation to ore deposits, but the biotite, tourmaline, garnet, other ferromagnesian minerals, and the sulphides that belong to the later hydrothermal stages of certain pegmatites, are probably derived from the parent magma by the same processes as similar minerals of ore-bearing veins, and indicate a relationship between the hydrothermal processes in pegmatites and ore veins.

Physical Character of the Late Residuum—Deep-seated magmas are intruded as liquids and may remain essentially a two-phase system of crystals and liquids until at least a late stage of crystallization, or, if gas escapes, a three-phase system. After concentration of volatile constituents has become high, several changes are possible. Morey[2] has pointed out that a large variety of substances in the magma are easily soluble in the hot residual solutions and each of these tends to raise the critical temperature. A plutonic magma as it cools becomes poorer and poorer in the non-volatiles and therefore the temperature at which it reaches the critical state will become progressively lower, but its actual temperature will, at the same time, become lower, and it is doubtful whether the descending curve of critical temperatures cuts the descending curve of actual temperatures (the solubility curve). Niggli[5] believes that critical phenomena play an important rôle, and applies the term "pneumatolytic" only to mineral deposits formed above the critical temperature. Fenner[6] and Bowen[7] both reject the idea that important mineral deposits were formed above the critical temperature, but believe that a gas phase may have played an active rôle. Bowen[7] believes that the gas phase escapes from a water-rich liquid phase after pressures have developed due to an advanced stage of crystallization which raises the vapor pressure until it is greater than the back pressure (the second boiling) point; in which case three phases—a solid, a liquid, and a gas—are present. This boiling is very different from the supercritical condition in which the fluid under pressure loses its meniscus and passes continuously, without change of composition and without absorption of latent heat, into a vaporous form. This escape from a residual solution is also accepted by Fenner, but is considered less important in the extraction of mineralizing materials than the early escape from a magma by boiling off of a gas phase immediately after intrusion.

Fenner[6] and Bowen[7] both point out that a residual liquid has been concentrated while in contact with the minerals of the rock; that is, it is saturated with all these minerals. A gas phase escaping from a liquid phase must be in equilibrium with that phase, and hence must also be in equilibrium with the minerals of the parent rock. Therefore, neither the liquid nor gas phase will be active agents for the chemical attack of the parent rock, or of a similar suite of minerals in any country rock they may traverse. If a material is deposited by one phase, it must also be deposited by the other, although the constituents with a low vapor pressure will be present in the gas phase in negligible proportions.

Travertine deposit now being formed by hot spring along a fracture near Jemez Springs, New Mexico. Photo by C. S. Ross

Segregation of Constituents

Segregation of Non-Volatile Constituents—Alkalic feldspars, quartz, and muscovite are late-stage minerals in the crystallization of a wide variety of magmas, even subsilicic ones; they form during the deuteric stages in the crystallization of igneous rocks, and they characterize aplites, pegmatites, and quartz veins. The concentration of these constituents in the residuum of the parent rock through the early crystallization of ferromagnesian minerals and calcic feldspar seems to deplete very thoroughly the residuum in such constituents as iron, magnesium, and lime; but garnets, pyroxenes, amphiboles,

[5]Niggli, P.: "Die lichtflüchtigen Bestandteile im Magma." Leipzig, 1920.

[6]Fenner, C. N.: "Pneumatolytic Processes in the Formation of Minerals and Ores. Ore Deposits of the Western States." Lindgren Volume, A.I.M.E., pp. 58-106, 1933.

[7]Bowen, N. L.: "The Broader Story of Magmatic Differentiation; Ore Deposits of the Western States." Lindgren Volume, A.I.M.E., pp. 106-128, 1933.

[8]Ross, C. S.: "The Copper Deposits of the Southern Appalachians." U. S. Geol. Survey Prof. Paper 179 (in press).

biotite, epidote and chlorite, minerals rich in these constituents, occur among the important gangue minerals. I have postulated[5] the removal from the earlier formed ferromagnesian minerals by solution, replacement, or base exchange, of ferromagnesian constituents through the action of a magma residuum which had previously been impoverished in these materials.

Segregation of Volatile Constituents—If boiling takes place within the cooling parent rock, due to the increase in vapor pressure, bubbles will rise through the interstitial liquid and constitute a fractional distillation column. Water is undoubtedly the dominant volatile constituent, but the rising bubbles also contain important amounts of the more volatile constituents and so the halogens will be relatively abundant. However, all of the constituents of the magma will be distilled into these bubbles in proportion to their partial pressures, but the quantities of all but the relatively volatile constituents will be insignificant.

Crater with fumarole. Valley of Ten Thousand Smokes, Alaska. Photo by E. G. Zies, Geophysical Laboratory, Washington, D. C.

In the liquid phase the halogens and other acid radicals will be neutralized by alkalies and other bases, but inasmuch as the halogens are much more volatile than bases, they will be more abundant in the gas phase than the liquid phase. We have seen that this gas phase will be in equilibrium with the crystal phase and will not be an active solvent for previously formed crystals, but should it condense, it will be an active solvent. Probably none of the silicates are entirely immune, but in general the ferromagnesian silicates are most readily attacked and the calcic feldspars only slightly less so. Thus, an acid hydrothermal solution formed by condensation is the medium most likely to restore iron, manganese, magnesium, and calcium to a residuum previously depleted in these materials.

It is improbable that the liquid phase is completely vaporized and if so there will be a commingling of residual and condensed fractions into a new solution which will carry residual as well as redissolved materials. These solutions will therefore carry alkalies and silica in addition to the other bases. As these solutions escape and lose heat, they will be capable of depositing a wide variety of ferromagnesian silicates, carbonates, and oxides.

Concentration of halogens in a gas phase has been used as an illustration, but of course other volatile constituents will also be concentrated, and these will tend to be evolved in the order of their volatilities. However, other factors may also serve to cause a sequence in the volatile materials. Fenner[6] has pointed out that evidence is available that volatiles are not immediately released on coming into a region of released pressure. Thus obsidians are known that have cooled at the surface while retaining 8 to 10 per cent of water. At 900 deg. C. this should exert a pressure of 2,000 to 4,000 atmospheres, corresponding to 7,500 to 15,000 meters of overlying rock. In a magma under pressure the constituents will be in all possible combinations and but few of these will be potentially volatile. On release of pressure new combinations will have to take place to permit evolution of gases, and there is evidence that this does not take place immediately. If this is so, some reactions will be slower than others and so promote a sequence in release of volatile materials.

A Definite Sequence

Hydrothermal Control of Mineralization—I have found[3] a definite sequence in widely separated copper deposits of the Ducktown type. The earliest group of minerals were pegmatites and aplites, followed by quartz. This was followed by ferromagnesian silicates, carbonates, lime silicates, and lastly by sulphides. The feldspar was probably derived directly from the parent magma as a liquid phase and the quartz by hydrothermal solutions. Materials forming the ferromagnesian silicates are believed to have been restored to the magma by reactions with previously formed minerals. The solvent material probably was acid in character, and inasmuch as halogens tend to be evolved in the earliest, hottest stages, they were probably the dominant acid material at this stage. Later, carbonates were formed in large quantities, and so CO_2 must have been abundant. Hydrochloric acid could not have been in excess while carbonates were being deposited, although chlorides may have been present. Quartz was replaced and removed during the formation of carbonates, and so the solutions were probably carrying alkaline carbonates and chlorides, which are most efficient solvents for silica. In the sulphide stage, immense quantities of sulphides—principally pyrrhotite—were formed, and thus sulphur in some form was the dominant volatile material present in addition to water. Carbonates were actively replaced, and so the sulphide-bearing solutions may have been acid in character, in contrast with a probably alkaline character during the preceding carbonate-forming stage. Changes of this character are not improbable, because, if they were acid at the source, the time during which they continued acid would be controlled by opportunities for neutralizing reactions. In these deposits therefore is found a marked sequence in the evolution of volatile materials. A gas phase may have aided in promoting this sequence, but the materials were transported and deposited by a liquid phase—a hydrothermal solution. A very large amount of material has been replaced, and in fact replacement and removal of material in some ways is a larger problem than introduction of material. It does not seem possible that materials having such a remarkably low volatility as calcium and magnesium could have been introduced as a gas phase in very marked excess over iron and other materials with higher volatilities, or that a gas phase could remove replaced material in an order that does not correspond to their volatilities.

For orebodies formed outside the parent rock agreement is general that the ore-forming materials were deposited by hydrothermal solutions. In general these are believed to have been dissolved and transported by hydrothermal solutions given off by the same magma from which the ores are derived. If these solutions have been concentrated as a late magma residuum, the ore-forming materials must have remained where they could be taken into solution by that hydrothermal residuum. Interspersed globules, therefore, rather than segregated sulphide masses, seem to be the most probable source of most ore deposits, and acid solution would be easily capable of dissolving and transporting such sulphide materials.

Alkaline solutions have been suggested as the carriers for metallic sulphides, but there is no exact agreement

Future Ore Supply And Geophysical Prospecting

Mineral Properties Now Entering a New Epoch

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IN THE United States in 1929, 55 per cent of all revenue freight hauled by Class I railroads consisted of "products of the mines." This classification included only mineral products before manufacture. If the same products after manufacture had been included, the total would have been approximately 75 per cent. Thus modern high-energy civilizations, as contrasted with all previous ones of a low-energy character, may truly be called mineral civilizations.

Modern industry may therefore be conceived of as one vast flow-line of

as to the extent of their solubility in such solutions. However, where quartz and quartzose rocks have been replaced, the active solutions were probably alkaline at the place where replacement is going forward.

Conclusion

This outline of the probable physico-chemical processes of ore formation lacks definite support in many places, and is in part only what seems the most probable relationships in the light of our present knowledge. I assume in accordance with the views of probably most geologists and experimental workers that segregation of mineralizing materials is a result of crystallization differentiation, but Fenner[8] believes that such materials are evolved for most ore deposits as a gas phase immediately after intrusions and before advanced crystallization of the magma. If this is so, mineralization (autometamorphism) of the parent rock will be absent. Evidence for a decision between the two theories can probably be best tested by the field geologist through evidence for the early or late formation of mineral deposits. Autometamorphism has been recognized in many places, but evidence for or against it should be carefully noted. One should remember, however, that ore-forming materials have differentiated by processes that tend to bring about equilibrium with the parent rock, and therefore their alteration is likely to be slight compared with the effect on invaded rocks.

The entire problem of the chemical character of ore-forming solutions is but vaguely understood. Their acid or alkaline character is in dispute. It is difficult to picture a solution that can in a single course of events dissolve and remove material from the parent magma, transport it to the place of deposition, and there drop its load only to dissolve and remove great quantities of replaced rock. We know a little about the solid materials and the acid radicals present through the minerals deposited, but we know next to nothing about the materials that failed to be precipitated and so left no record behind. We know but little about the ranges of stability of large groups of minerals. We talk about high and low temperature deposits but allow a wide range for the actual temperature of our guess.

The field geologist and mining engineer have much to contribute in solving these problems. Perhaps I may here emphasize that gangue minerals, which have at times been neglected in studies of ore deposits, probably are capable of revealing important information about the intermediate stages of differentiation that lie between magma processes and ore deposition. Theories of ore deposition must be rigorously tested in the field, but this demands an understanding of geologic implications of physico-chemical experimental work.

Much of the information required to clear up problems of ore deposition can be supplied only through physico-chemical research. In the past, numerous experiments have been made on the solubility of ore materials in first one possible solvent and then in another. Such haphazard experiments are now completely outmoded and only detailed phase relation studies of minerals and their possible solvents are capable of giving the necessary information. A beginning is being made in the study of systems containing water, and the methods are being worked out. Phase relation studies reveal relationships quite incapable of discovery by any other method. The recent paper by Bowen, Schairer, and Posnjak[9] on the anhydrous system $CaO\text{-}FeO\text{-}SiO_2$, for instance, has revealed relationships that the older methods could not possibly have revealed; and it is evident that phase relation studies of systems containing volatile materials will yield equally unlooked-for results. Evidently our science is in vital need of much more extended research along physico-chemical lines, which applies particularly to ore-deposition problems.

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[8]Bowen, Schairer, and Posnjak: "The System $CaO\text{-}FeO\text{-}SiO_2$." *Am. Jour. Science,* Vol. 26, pp. 193-284, 1933.

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minerals flowing from the earth by way of the mines into industry, and finally, by wastage and chemical disintegration, returning to earth again. This flow begins at the mineral deposits of relatively high concentration and ends in a dissemination of low concentration, or a scattering, so to speak, to the four corners of the earth. It is, therefore, a unidirectional and non-reversible flow. Minerals, though never destroyed chemically, are mined only once, and, after being wasted, are not likely ever to be collected together again.

The first stage in this mineral flowline is that of prospecting and discovery. For the rate of flow of minerals from known geological reserves into industrial uses to be constant over an extended period of time, the rate of discovery of new reserves must equal the rate of exhaustion of the old ones. Thus one sees that the flow-line involves a whole industrial complex, and that any attempt to discuss prospecting alone without taking into account the factors determining the rate of flow of the whole would be essentially futile.

Mineral Distribution

The practical depth limits of mining and of the production of petroleum up to the present have been of the order of two miles from the earth's surface. Although this will doubtless be increased, discussions involving mineral distribution in the upper two miles of the crust are not likely to be invalidated for greater depths.

The outstanding characteristic of the distribution of any particular mineral, such as iron, is that in by far the greater part of the upper two miles the product occurs in very low concentration. On an average, the surface rocks contain only 8 per cent aluminum, 5 per cent iron, and 2 per cent magnesium. All of the other metals commonly used in industry occur on the average only in small fractions of 1 per cent.

Fortunately for civilization, in a very small per cent of these rocks higher concentrations of the useful minerals occur. To represent this graphically (Fig. 1), one may draw a rectangle the area of which represents all the rock in, say, the upper two miles of the crust. Now, supposing that this rectangle be divided into vertical columns from left to right, arranged in the order of the concentration or percentage by weight of some industrial metal, say, iron, one would find that a very narrow column at the extreme left had the maximum iron content of a little over 72 per cent. This would represent an iron ore of pure magnetite with no gangue mineral. The iron content of the next column to the right would decline to 70 per cent (pure hematite), then to 50, to 30, and to 20. From each of these to the next, the decline would be somewhat more gradual, with a broad plateau in the vicinity of 5 per cent. Finally in the narrow columns at the extreme right it would probably decline sharply towards zero.

Even if exact data were available, it would be difficult to draw such a graph accurately, because of the extremely narrow range of the higher concentrations. Curves similar to Fig. 1 but with different ranges in the concentration would be true for each of the other industrial metals.

The significance of such curves is that the greatest quantity of any metal occurs in very low concentrations, and, although this could possibly be extracted and refined, the physical cost in energy expenditure would be extremely high. In general, the higher the concentration, the smaller the physical cost of extraction per ton of final product. This condition forces the mining industry to begin at the available deposits of highest metallic concentration, and, as these are

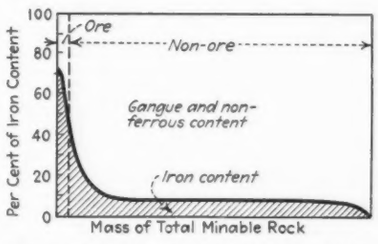


Fig. 1—Graphic representation of the occurrence of the higher concentrations of iron in relation to the volume of total minable rock

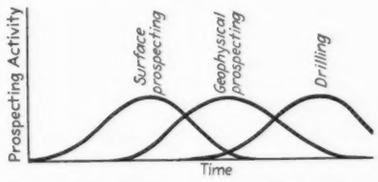


Fig. 2—Sequence of prospecting operations in present-day examination of mineral properties

exhausted, work down gradually to those of lower and lower metallic content.

England, for example, formerly mined iron ore of over 50 per cent iron content, but is now reduced to working 30 per cent ores. In the Lake Superior region, the average grade was formerly 60 per cent and better, but now is 51 per cent, with reserves of this grade sufficient for only fifteen or twenty years more at the 1929 rate of production.

This mining of lower and lower grades of ore progressively, with the consequent mounting of physical costs of extraction, places a premium upon the discovery of hitherto unknown reserves of higher-grade deposits.

Sequence of Prospecting Methods

In the initial exploration of any large land area for useful minerals a natural sequence of methods is employed, which also depends upon physical costs. The first method is that of reconnaissance exploration, followed later by more detailed study, involving essentially the old-fashioned surface prospecting methods. All of the "easy" discoveries are thus eventually made. In other words, there is a certain time period in which the rate of discovery of minerals increases with increased intensity of surface prospecting. Then the rate of discovery declines in spite of increased intensity of prospecting.

A more refined and systematic form of surface prospecting which usually succeeds the original and more or less haphazard initial form is that of geologic mapping. This may result in a few more discoveries. After that, surface methods are of little further avail. This is borne out in both Western Europe and the United States, the two principal mineral areas of the earth, when one considers that, as Leith has pointed out, there has not been a major mineral discovery, save for oil and potash, in the United States since 1915 or in Europe since 1850.

The decline in the rate of discovery has occurred in the face of the most spectacular growth in the rate of consumption of minerals and a corresponding increase in the intensity of surface prospecting and of geologic mapping the world has ever known. It seems fair to conclude that for these two areas the days of discovery by surface methods are almost over.

Geophysical Work

Most of the possible discoveries in any area having already been made by surface methods, two possibilities remain: (1) other major undiscovered deposits do not exist, or (2) such undiscovered deposits do exist but have not been brought to light by surface methods.

As for the first, if other deposits do not exist, no amount of exploration will yield discoveries. The high-grade deposits will in time be exhausted, and mining operations will fall back upon ores of continuously lower grade, with physical cost of production simultaneously mounting. This process will continue for any given district until the grade of ore becomes so low and the physical cost so high that mining will cease.

As for the second possibility, it is highly probable that in any large area other high-grade ores may exist, but simply are not detectable by surface methods. The problem of discovery remains. Direct methods can be used, involving exploration pits, drill holes, or shafts, and, if enough of such work were done, one could be assured that any hidden ore deposit would be discovered. The restraining factor is physical cost; in this case, the cost per unit discovered. Because of this factor, drilling as a form of prospecting can be indulged in only after data have indicated a high probability of discovery.

Finally, only the last alternative remains: discovery by indirect methods

involving a relatively low physical cost per unit discovered. This is the domain of geophysical prospecting. To recapitulate: in any mineral area there is a definite sequence of prospecting methods arranged in the order of their cost per unit discovered. This is: (1) Surface prospecting. (2) Geologic mapping. (3) Geophysical prospecting. (4) Drilling. This sequence is true historically for a region. Since the advent of geophysical prospecting, it is the approximate sequence in the present-day examination of individual properties (Fig. 2).

Inasmuch as geophysical prospecting methods have entered the scene chiefly since 1920, it may be worth while to consider briefly the probable future trends in the design of apparatus and development of technique. The major possible applications of geophysical methods appear to have been already tried sufficiently to indicate that in the future no departure from magnetic, electrical, and seismic fields as the most productive of the domains of geophysical prospecting is likely to occur. Already a pronounced trend is discernible toward limiting apparatus to a few simple kinds having maximum sturdiness and sensitivity, combined with decreasing weight. Apparatus is being evolved toward an automatic instrumental elimination of extraneous factors from the observed data, so that quantities observed are becoming more and more closely related to the unknown sought. At the same time, theory is being improved and computing methods are becoming more simple and graphical.

In reflection work in seismology, reliable reflections are being obtained at progressively greater depths with decreasing quantities of dynamite per shot, until depths of 12,000 ft. are being attained with dynamite charges of the order of 1 lb. per shot.

All of these trends will continue, but the future of apparatus and technique promises to be largely an orderly evolutionary development concerned with the perfection of details rather than abrupt departures of a "mutational" sort, characteristic of the early stages of development in the past decade.

Viewed on any long-time basis, the mineral industries appear to be just now entering what might be termed the "geophysical epoch" of prospecting. By no means is it accidental that surface geological mapping in the oil industry was largely supplanted between 1925 and 1930 by subsurface mapping from well-log data and by geophysical methods. The old surface methods had had their day, and, if more oil were to be found by methods less expensive than by "wildcat" drilling, geophysical methods were the only alternative.

Promising Localities

Another question that might well be considered, particularly as regards metallic ores, is that of the geologically

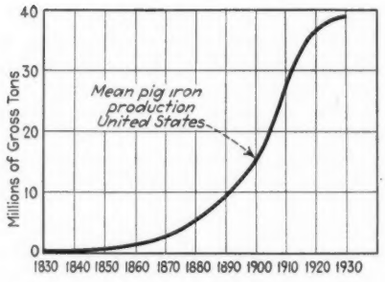


Fig. 3—Curve showing mean production of pig iron in the United States, 1830-1930

probable localities from which discoveries during the "geophysical epoch" of prospecting are most likely to be made. There is always a high probability of other deposits being hidden in the vicinity of known deposits. Many of the future geophysical discoveries will consist essentially therefore in determining the extension of known deposits.

Among the most fertile areas for deposits of metallic minerals thus far known have been the great Pre-Cambrian shields, such as the Canadian and the Baltic. Inasmuch as both of these regions were extensively glaciated during the Pleistocene, large areas are now covered by lakes and glacial drift. That such hidden areas may contain important metallic deposits is highly probable. Recent geophysical discoveries in these areas in both Sweden and in Canada have sustained this supposition.

Besides being covered in parts with glacial drift this same basement complex extends everywhere beneath the younger sediments. In these areas it has remained almost entirely unexplored to date. The geophysical prospecting of the future may quite probably make some of its most important discoveries in such regions, especially where the sedimentary cover is not too thick. The famous Kursk magnetic anomaly in the plains of Russia may be considered a forerunner of future discoveries in such regions.

Mountains and their igneous rocks also afford probable localities for future discovery.

From the foregoing the reader may see that I consider the increasing use of geophysical prospecting methods to be but the natural consequence of the progressive exhaustion of known high-grade mineral deposits in any particular area. Inasmuch as the world is now entering seriously this phase of its evolution, we may confidently expect the immediate future to witness a rapid acceleration in the application of these methods. The proven high-grade reserves of most of the world's minerals will suffice at 1929 rates of production only for some decades, after which they must either be supplemented through new high-grade discoveries or else world production must be derived thereafter from low-grade deposits at great expense. The latter alternative will force the mineral industry to make the widest possible use of geophysical methods.

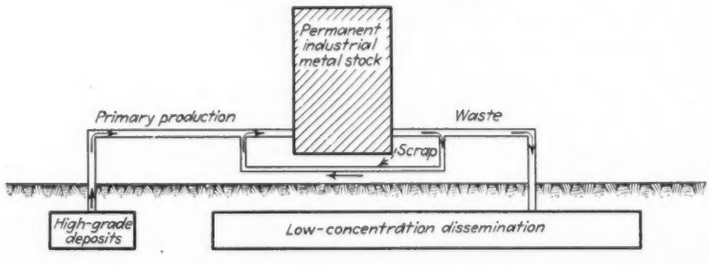
As already pointed out, regardless of how fast or how slow the process may be, the one fundamental trend of all mineral movements is from high-grade deposits to complete scattering in low-concentration dissemination. This is a non-reversible process, so there can be but one ultimate answer: namely, that all high-grade deposits will ultimately be exhausted. As said at the outset, prospecting and discovery constitute the first step in this progression.

During the last 100 years the rate of growth of mineral exploitation has been so spectacular that many have been led to assume that the rate would continue more or less indefinitely. If this were so, the various phases of evolution considered would be much shortened. Certain important restraining influences, which until recently have been comparatively obscured, tend to retard this rate, however, by prolonging the time period of each phase.

From 1870 to 1915 the growth of pig-iron production in the United States was almost a perfect exponential curve at an instantaneous rate of increment of about 5 per cent annum. Most of the operations of the iron and steel industry until recently have been based upon the premise that this rate of increment would continue indefinitely. Simple computation would show that to continue such a rate of growth for another 50 years would require an amount of iron equal to a considerable fraction of the entire earth—an amount greatly in excess of our available resources or of our ability to consume.

One is not surprised, therefore, to find that from 1920 to 1929 the average annual production of iron in the United States has remained practically constant.

Fig. 4—Schematic diagram illustrating the flow of metal from the ore deposit into industry, thence to re-cycle as secondary metal or to be lost through dissemination



What is thus pointed out with regard to iron is equally true for coal, copper, and most of the other principal mineral resources. After a period of spectacular growth comes a leveling off of production suggesting a saturation of the ability to consume, in cases where the decline cannot be ascribed to the inability to produce.

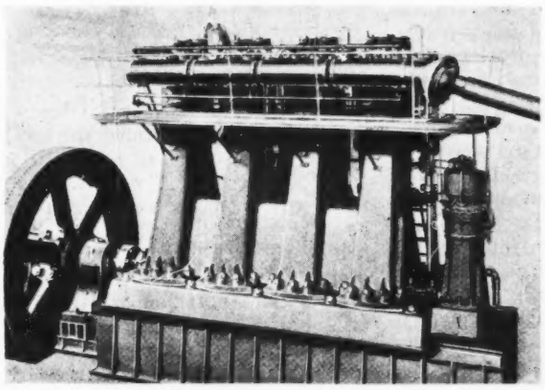
At the outset, I stated that the mineral flow-line included three essential stages: (1) Mining, or primary production. (2) Industrial use. (3) Wastage. This is exactly analogous to a pipe line into and out of a surge tank (Fig. 4). The primary production corresponds to the input; the stock of metals retained permanently in industrial use represents the fluid stored in the surge tanks; the wastage of minerals after use represents the outflow from the tank. Obviously, the input can be maintained at any given rate only if either the amount in the tank is increasing or the outflow is equal to the input per unit of time.

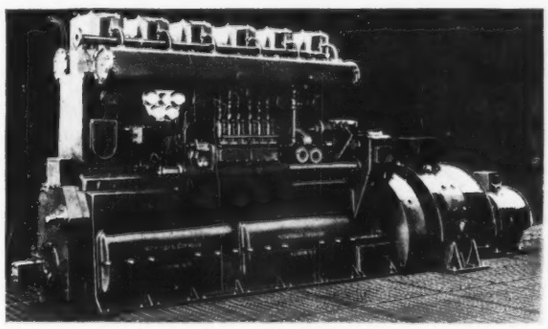
In the past, the outflow or wastage has been large, and the quantity retained in industrial uses (except in the case of consumables such as fuel) has been continuously increasing. Each of these factors has caused an increased demand upon primary production.

At present, one of the outstanding trends in metals is that of the increasing use of scrap. In the United States in 1929, for instance, primary production of copper was about 1,360,000 short tons, whereas at the same time secondary production was as high as 400,000 short tons, or approximately 30 per cent of the primary. Within the last year secondary production has risen to over 90 per cent of the primary. This trend is also discernible in other metals—iron, zinc, tin, lead, nickel, aluminum, and antimony—and can be expected to become increasingly important in the future. All the secondary metals thus recovered make it unnecessary to draw upon an equal amount of primary metals. This retards primary production by that amount.

The other factor in the flow-line of metals affecting the rate of future primary production, and hence of future discovery, is that of the quantity of metals retained as a permanent circulating stock by industry. In the past, railroads, factories, power systems, and telephone and telegraph systems had to be built, each requiring its quota of metals, mostly primary. Hence the quantity in the surge tank, so to speak, was increasing and the capacity of the tank was large.

Today this is largely over. The one fundamental trend in modern industry is toward speed. Almost every new plant or piece of equipment runs faster than its predecessor. Witness the steam turbine as compared to the Corliss reciprocating engine of the same horsepower rating. In the meantime, the production output of modern industry as a whole is rapidly leveling off and will in all probability continue to do so.





Less metal per brake horsepower is required in the lower of these two diesel engines than in the one above it. The upper, an old-style unit, develops 500 hp. and weighs 400 lb. per b.hp. The lower, of modern design, develops 450 hp. and weighs only 113 lb. per b.hp.

Putting these two things together—a leveling off of industrial production together with an increase in the tempo of industrial processes—one gets a significant result. A physical relationship applies to all physical equipment to the effect that the faster any machine operates with a given output rate, the smaller it needs to be. This is true whether applied to simple individual apparatus, such as power-transmission belts, pipe lines, and individual motors, or to whole factories, to office equipment, or to a whole industrial complex. *Quite generally, for a given productive output rate the faster the apparatus is made to operate, the smaller it will tend to become.*

Granting this, it is entirely possible and not improbable that in North America in the near future the industrial plant may contract to such an extent that the available secondary metals may for some time almost entirely supplant those from primary sources. This will tend to delay the time of exhaustion of known high-grade deposits and will prolong the length of the "epoch of geophysical prospecting."

Foreign Trade

Proposal is not infrequently made that a way of getting rid of present primary minerals be instituted by such practices as raising the Chinese standard of living to that of the United States. If this were seriously attempted it would get rid of the minerals, but not by appreciably raising the level of the Chinese nearly so much as by reducing the level of the American standard. This is true for the simple reason that American resources are not nearly adequate to stand any such form of international philanthropy indulged in for reasons of business expediency.

Another reason why such a course is not likely is that no country can possibly maintain for more than a few years what is known in economics as a "favorable balance of trade." This consists in shipping out more goods than are allowed to be shipped in. A perfect trade balance, following the above logic, would consist in shipping out all and receiving nothing in return!

Both domestically and internationally, auxiliary minerals move to centers of industrial activity—centers of coal and iron. Iron ore moves to coal. Tungsten moves from China to Europe and to North America. Oil moves from Colombia and Venezuela to the United States and to Europe—not automobiles from these latter places to South American oil. This sort of thing, aside from temporary interferences, is likely to continue in the future. If it does, the rate of mineral production in North America is likely to continue to be largely for domestic consumption. This will not so much postpone geophysical prospecting as lengthen the period of time during which it will be found useful.

Mining Technique And New Research

Rock Stress Studies Will Eliminate Some Guesswork

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OUR present state of civilization has a vital need for the study of fundamentals, the display of constructive imagination, and clear thinking. The engineering profession has been remiss in these matters. Most constructive research work of mining engineers can properly be classified under other branches of engineering, yet, erroneously, the profession of mining is customarily associated in the thought of many only with the removing, breaking, and transportation of rock, without consideration for the fact that the development of the means and appliances requires the practice of the more specialized engineering professions, besides the initiative, extensive knowledge, experience, and self-sufficiency which the mining engineer should possess because of the remoteness of mineral deposits from centers of population. Special emphasis may therefore be placed on the research project here discussed, because it deals with a phase of engineering so intimately related to mining as to warrant the name "petrodynamics," or the study of rock structures under stress.

An Interesting Invention

Many of our important inventions are based upon simple and well-known concepts applied to new uses, and so it is with the centrifuge invented by Philip B. Bucky, assistant professor of mining at Columbia University, and described by him in T. P. 425 of the American Institute of Mining and Metallurgical Engineers, February, 1931. Through its use can be determined for the first time experimentally in the laboratory the behavior of many structures bearing self-imposed and external loads, and the uncertainty of calculated results which may include a false or incomplete hypothesis can be avoided. Investigation of the behavior of rock and earth excavations and subsidence has long been needed by the mining and contracting industries, and this need was the incentive which prompted the development of Professor Bucky's special centrifugal testing machine. The possibilities were quickly realized and supported by Dr. G. B. Pegram, who obtained the necessary financial assistance, which is now being augmented by the Engineering Foundation.

Although the principles of operation are simple, Professor Bucky has had to apply his ingenuity earnestly to solve the practical mechanical difficulties contingent to the instantaneous observation, measurement, and photography of the changing states which occur in a structure which is stressed to and beyond rupture. With the limited funds available, the solution of such problems has necessarily been slow, and even his newly completed centrifuge is not more than one-fifth the desirable size. Chief among the problems met in the construction of these machines are: elimination of vibrations at high rotational speeds; reduction of windage losses; provision of an adequate intensity of illumination upon the entire model so as to enable motion-picture photography of the model under test; the high-frequency intermittent character of such illumination demanded by the required stroboscopic effect; and the assembly of an optical system which made possible the observation of a body rotated at high speeds.

Because of a distaste for the formulas of mechanics, many engineers have failed to appreciate the need for such a special method of testing. This inability to visualize the difficulties inherent in the use of models has left a vagueness which resulted in ill-considered expenditures on special loading tests of models. This has delayed cooperative interest in and reliance upon the special apparatus which Professor Bucky has designed for the testing of structures. I think it therefore proper and desirable to restate in different words the underlying principles which Professor Bucky has enunciated. Formulas are merely mathematical shorthand, and for their readers who prefer such short cuts we will express them.

Dimensionality of Functions

The need for some special method and apparatus such as that of Professor Bucky comes from the dimensionality of functions and its influence upon the values for scale models. If we say that a model is built to one-tenth full size, what do we mean? Do we mean that it has one-tenth the volume? No. We mean that if we measure any corresponding *linear* dimension on the model, such dimension will be one-tenth that of the prototype. Assume that the prototype is a cube of brass 10 in. long, 10 in. broad and 10 in. high. Its volume would be 1,000 cu.in., its mass the product of that volume times the density of brass, and its weight such mass times the acceleration of gravity (g), so $W = 10 \times 10 \times 10 \times d \times g = 10^3\, d \times g$. If a one-tenth scale model is constructed, it must be of brass, but its length, breadth, and height will each be only 1 in. (one-tenth of the linear dimensions of the prototype). So the volume will be 1 cu.in., or only one-thousandth of that of the prototype, and inasmuch as model and prototype have the same density of material and each cubic inch of material in both is acted upon by the same, so called, "attraction of gravitation," therefore the weight of the model is only one thousandth of the prototype's weight. Evidently such a fundamental physical property as weight is not constant nor even proportional to the *linear scale* of a model, and for exactly equivalent reasons the other structural properties of a model are not constant, but may, as in the case of unit stresses, bear a simple linear relationship to those present in the prototype.

We will remember that forces tend to produce motion, that such motion is accelerated if the force is constantly applied, and that such acceleration has a value depending only on the size of the force and the magnitude of the mass upon which it acts, so $F = m \times a$ (force equals mass times acceleration). The weight of a body is the evidence of the force of attraction exerted between its mass and that of the earth, such evidence being observed only when we restrain the mass from motion towards the center of the earth. So we can express all forces in the common terms of mass times acceleration or in the special terms of the weight units which apply only to the gravitational system, and our accelerations may be referred to as so many times the acceleration of gravity.

The weight of a rectangular body we have found to be the product of length, breadth, height, density, and the acceleration of gravity, and it can be simply expressed as $W = (lb \times h)\ (d \times g)$.

The weight for a one-tenth scale model is

$$W_{0.1} = \frac{l}{10} \times \frac{b}{10} \times \frac{h}{10} \times dg$$

$$\text{or } W_{0.1} = \left(\frac{lbh}{1000}\right)(d \times g).$$

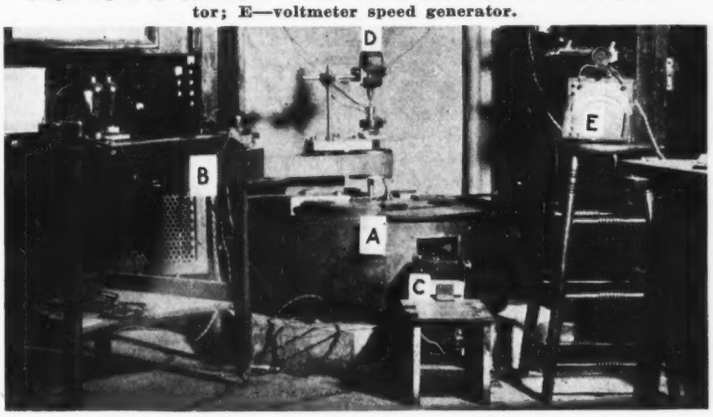
If it be desired to construct a model that has such a physical property as its weight the same as that of its prototype, and the scale of the model be one-tenth, then it is necessary for the product of the density times the acceleration towards the center of the earth (artificial "gravity") to be 1,000 times the product of those quantities of the prototype. Inasmuch as no means exist for changing the density of a substance without changing its composition, structure, and structural characteristics, we must turn our attention to the factor of acceleration as the sole means for making laws of similitude possible between a model and its prototype. If we can produce and control a sufficiently large field of force coincident with and additive to the gravitational field, we can satisfy the requirement that the model have a weight equal to that of its prototype. To make observations of the model under such conditions, it must be restrained; so that its projection in a rocket would not be a practical solution, and even though the observer could be a passenger, such an acceleration would be too great for the structure of the human body to stand.

Professor Bucky thought of a simple and highly practical solution—namely, the use of the central accelerations obtainable from restrained uniform circular motion (the same centrifugal forces so well known in centrifugal separators for milk and other substances, and so noticeable in the occasional bursting of flywheels). Determination of the acceleration producing the requisite restraining *central forces* is simple, because it varies directly as the square of the speed of a point moving in a circular path (the magnitude of the tangential velocity), and inversely as the radius of gyration of the prescribed mass. If we deal with units of length and time represented by feet and seconds, and units of acceleration in terms of that common to gravity (about 32.16 ft./sec.^{2}), and if we measure the radius of gyration and the revolutions per minute at which we operate a centrifugal machine, we can determine the central acceleration as follows: When a mass travels in a circular path of fixed radius (in feet) at a uniform angular velocity of so many revolutions per minute, its linear speed is $2\pi r \left(\frac{\text{r.p.m.}}{60}\right)$ in feet per second and the square of this speed is $\frac{(\pi^2)}{900} r^2 (\text{r.p.m.})^2$, or equals $(0.0109662)\ r^2\ (\text{r.p.m.})^2$. Inasmuch as the square of the speed divided by the radius equals the central acceleration, the latter equals $0.0109662\ r\ (\text{r.p.m.})^2$. Professor Bucky's original centrifuge permitted mounting models at an active radius of about 8 to $8\frac{3}{4}$ in., or an average value of 7/10 ft. may be assumed; and the maximum speed of the centrifuge was about 4,000 r.p.m., so the maximum central acceleration was $0.0109662 \times 0.7 \times 16{,}000{,}000 = 122{,}821$ ft./sec.^{2}. In terms of the acceleration of gravity (at 32.16 ft./sec.^{2}), the maximum model acceleration was $122{,}821 \div 32.16 = 3{,}819$ times gravity. His new centrifugal machine has an active radius of about 2 ft. and a maximum model speed of 2,200 r.p.m., so that the model acceleration reaches a maximum of 3,100 times gravity for the center of mass of a model whose dimensions are 12 in. × 12 in. × 3 in. thickness.

Another Consideration

The next important consideration is the relationship between the acceleration, in terms of the number of times gravity, of a model and the scale factor applying between the model and its prototype. Actually, the stresses in a model approximate those due to the earth's gravitational field on its prototype if the model is subjected to an acceleration in a horizontal plane equal (in units of gravity) inversely to the multiplier scale of the model. For example, if the model is one-tenth normal size, it should be rotated horizontally at a speed which makes the central acceleration ten times that of gravity; therefore 321.6 ft./sec.^{2}.

New centrifuge and accessory equipment. A—centrifuge; B—stroboscopic light equipment; C—movie camera; D—speed counter generator; E—voltmeter speed generator.



The structural functions which we are interested in determining by testing models in such a centrifugal machine have to do with unit forces, stresses, and pressures. Inasmuch as stresses and pressures are the effects or resultants of forces, and inasmuch as any unit value is the quotient of the total force or effect by the area of section or surface involved, we may arrive at the dimensional characteristics of a unit force, stress, or pressure. Remembering that all forces may be expressed as the product of a mass times acceleration (therefore a volume times density times acceleration), and so are equal to density times an acceleration times a three-dimensional quantity, and remembering that the divisor is an areal quantity of two dimensions, we can readily realize that the quotient, unit stress, is always equivalent to a density times an acceleration times a one-dimension quantity which bears the scale factor. Consequently, for the unit stress to remain constant the acceleration must vary inversely as the scale factor.

Therefore, whatever scale multiplier is used for the linear dimensions of the model (in reference to its protoype), the same multiplier appears in the function representing the unit stresses or pressures normally present in a model. To produce the same stresses in a model as the acceleration of gravity produces in its prototype, we must accelerate the model as many times the normal gravitational acceleration as the inverse quantity of the scale of reduction from the prototype to the model size, provided we are rotating the model in a plane at right angles to the direction of normal gravitational acceleration, as does Professor Bucky in his centrifuge.

The Proof

The proof of this general statement is readily apparent if the scale factors are substituted in each of the original prototype dimensions and the ratios between unit stresses in a prototype and its model are determined for the various formulas for the unit stresses of shear, tension, and compression in respect to the structure of beams, columns, arches, and retaining walls. But I hope the foregoing explanation will make needless any such reference to formulas.

For example, if we wished to know whether a pillar of certain cross-section and height would support a given volume of roof load, and a scale model were made of the same rock and rotated at a speed which produced a central acceleration as many times gravity as the linear ratio of the prototype to the model, the true behavior of such a pillar would be observed.

The demonstration of this by formulas may be made in a general manner for the simple function of unit pressures on the bases of the cubes already mentioned, where l and l_1 are the lengths of the edges of the prototype and model cubes, respectively; m and m_1 their re-

spective masses for volumes V and V_1 and densities d and d_1; A and A_1 the areas of their respective bases; g the gravity acceleration of the prototype and "a" the acceleration of the model; P and P_1 the total respective pressures on their bases, and p and p_1 the corresponding unit pressures; and K the scale factor of the model and therefore equal to l_1 divided by l. Then

$$P = mg \text{ and } P_1 = m_1 a$$

$$\text{also } p = \frac{P}{A} \text{ and } p_1 = \frac{P_1}{A_1}$$

but $m = V \times d = l^3 \times d$ and $m_1 = V_1 \times d_1 = l_1^3 \times d_1$ also $A = l^2$ so $p = l \times d \times g$ and $A_1 = l_1^2$, and $p_1 = l_1 \times d_1 \times a$

$$\text{and since } K = \frac{l_1}{l}, \text{ therefore } Kl = l_1 \text{ and } p_1 = Kld_1a$$

If it be required that the material, and therefore its density, remain constant, then $d = d_1$; and if, furthermore, the unit pressure on the base of the model must equal that of the prototype, then $p = p_1$. Therefore it follows that $l \times d \times g = K \times l \times d \times a$, and inasmuch as ld cancel out, then $g = K \times a$, and $a = \frac{g}{K}$, or $\frac{a}{g} = \frac{l}{K}$. Thus it is evident that the acceleration of the model must equal the acceleration of the prototype multiplied by the reciprocal of the scale factor; also that the same relationship would hold for the unit pressures on any other corresponding sections of the prototype and its model.

Laws of Relationship

A unit pressure is merely a special type of stress function, and any unit stress is the quotient of a force divided by the area on which it acts $\left(S = \frac{F}{A}\right)$. Therefore tensile and compressive stresses are in the same category as unit pressures. In consequence, the following general laws of relationship may be stated in respect to models and their prototypes:

(a) Under similar conditions of loadings by forces on the model which bear a ratio to the forces on the prototype inversely proportional to the scale factor of the model (the ratio of any linear dimension of the model to the corresponding dimension of the prototype), all unit stresses in the model will be equal in magnitude, direction, and corresponding location to those in the prototype.

(b) Inasmuch as identical physical properties are possessed by only identical substances, the unit masses of both model and prototype must be identical, so a change in the forces may result only from changes in the acceleration of such masses in a manner to satisfy the first law.

Advantages

The following advantages inherent to this centrifugal method of testing have been noted from the experiments made to date:

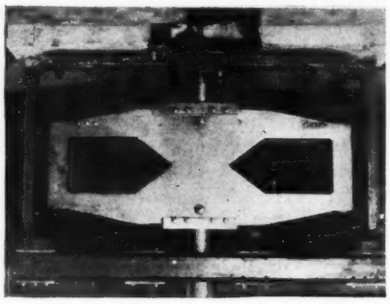
1. The normal and well-known laws of mechanics in regard to beams and columns can, in general, be applied to the rock structures of mines when the elastic limits of the materials have not been exceeded.

2. Beyond the elastic limits and up to the state of rupture mathematical calculations cannot give a correct solution, and such experimental demonstrations as can be given centrifugally alone give truly reliable predictions. Experimental curves can be plotted to which any desired safety factor can be applied for utilization in field work.

3. A great diversity of experiments can be carried out in a relatively short period of time and at a nominal expense, and therefore many minds may attack the same problem simultaneously.

4. This method is applicable to the investigation of the flexure and permanance of all type of structures and to any kinds of materials, both solid and fluid.

5. It is the only method developed to date whereby tests may be made, on an authentic reduced scale and of identical composition and similar form, of structures under definite forces and loadings and concerning which a prediction of their behavior is required.



The new centrifuge, also shown on p. 23

Tests Made

The following tests have been performed:

1. Determination of the maximum roof spans which can be safely employed in mine openings.

2. Determination of the effect of arching upon the span which can be safely worked.

3. Investigation of the behavior of a roof when various types of supports, such as pillars, props, cribs, and bulkheads, may or may not prevent impact effects from roof failure.

4. Determination of the maximum depth to which open cuts may be excavated under overhanging walls of various slopes.

5. Investigation of the effect and behavior of props which support mine roofs.

6. Observation of the effects of closed and open vertical cracks, respectively, upon the behavior of mine roofs.

7. Determination of the angles of repose (slope) of various loose materials, and the influence of particle sizes upon such slopes.

8. Determination of the suitability of rock or ore structures for block-caving methods; the size of the block; the area and height of the undercut; the need for shear cuts at the sides of the block; and the methods for control of the size of the broken material.

9. Determination of the dimensions of undisturbed overlying rock and ore to prevent surface subsidence on account of mine openings.

10. Prediction of the surface area affected by subsidence, the amount of surface subsidence, the system of cracks likely to develop, and the effect of subsidence upon surface structures.

Prospective Uses

Mining

1. With the availability of centrifugal testing for the study of rock structures and wood, concrete, and steel mine supports, rule-of-thumb methods will be supplanted by a unit engineering control of mining methods.

2. Specific surface area will be delineated as subject to subsidence.

3. The influence of mine openings upon the formation of fissures and water drainage will be anticipated.

4. The effect of surface topography upon underground stresses and those in the walls of open cuts will become apparent.

5. Determination of the factors which encourage and control squeezing ground, rock bursts, or pillar spalling.

6. Simulation of rock conditions at great depths and the study of rock flowage under such depths.

7. Studies of filling methods, their need and behavior.

8. Determination of whether rigid or compressible roof supports are to be preferred.

9. Determination of the most economical plan for roof support and the size and distribution of ore pillars.

10. Determination of the sizes of rooms and pillars for districts where retreating methods of mining are feasible.

Civil Engineering

1. The testing of models representing welded structures for bridges and buildings.

2. The testing of models of concrete structures and foundations.

3. Determination of the supporting power and behavior of soils both for ordinary foundations and for piles.

4. Test of the overturning moments of foundations in earth and gravel.

5. Design and testing of models of bins and the flow of material contained therein.

6. Testing of models of dams and retaining walls.

7. Hydraulic studies, such as stream flow, the transporting power of streams, and the production and effects of tides and waves in large bodies of water.

8. Photo-elastic studies of the distribution of stresses in models of beams and columns under dynamic loadings.

Aeronautics

1. Determination from tests on a model of the largest-size plane which can be safely operated of the same design.

2. Wind tunnel tests of lifting power performed with models and a wind tunnel mounted centrifugally.

3. Tests of the structural design of the braces, struts, and tension members of airplanes made on a small scale.

Geology

1. The study of mountain-forming processes—isostasy, folding, and faulting.

Removing a Doubt

Doubts have existed in the minds of some engineers as to the practical value of this centrifugal method of testing rock structures, because of the lack of homogeneity of many rock formations and the presence of uncertain stresses, faults, fractures, and cleavage planes in rock formations. The argument is advanced that no structural model can fairly represent such unknown conditions and that therefore this method of testing has only academic interest and might even be charged of giving an improperly false sense of security if excavations were planned upon the basis of model tests.

Obviously, if it is impossible to get a representative sample of rock formations it is equally impossible to establish any sound premises of rock strengths, upon which an engineer could properly base any intelligent plans for the size of excavations which will be self-supporting. He cannot design with a background of experience without granting that the variables fall within known limits which permit him to count safely upon certain roof spans and pillar supports in planning the development of a mine. He arrives at such conclusions by trial and error on a large scale, with unwarranted expense and time delay, when the centrifugal testing of a series of different structural samples of the various rock structures can just as surely indicate what to expect.

Safety Factor

Because of the lack of homogeneity in the composition and physical state of all structural materials, the uncertainty of unforeseen damage to them and loadings upon the same, the engineer must always multiply his design calculations by the proverbial "Factor of Safety," more truly called a "Factor of Ignorance." He would naturally use the same procedure in applying the data he obtains from the centrifugal testing of structural models. In short, this new method of testing may become a valuable tool in the hands of those whose special experience and training permit them to interpret properly, and practically to apply, the data which may be developed through it.

To be completely frank about the future prospects of centrifugal testing of models, I must make public disclosure of my own ideas for a machine and method which I feel will permit different and broader applications in the testing of structural models than are offered by Professor Bucky.

In the machine already described the model is subjected to two accelerations at right angles to each other—namely, the central acceleration in a horizontal plane because of the centrifugal effect, and also the acceleration of gravity which acts at right angles to that plane. The stresses in the models are due to the resultants of these accelerations. The added vector of the acceleration of gravity has not been given consideration in any of the published calculations and articles. Where the model is tested at accelerations many times the acceleration of gravity, such a consideration is likely to be more of academic than practical importance; but where it is desirable to test a model under accelerations ranging more closely to the accelerations of gravity, the discrepancy makes the method unsuitable. In this machine it is also impossible to investigate a mass freed from any resultant acceleration. Again, at a constant rotary velocity all self-loading is static rather than dynamic. Of course, variations in the revolutions per minute of the centrifuge will give dynamic loading, but cyclic repetitions of such slight variations of loadings as are necessary to give a "live" loading effect rather than a static loading, are subject to great difficulties in the present machine.

Investigating Minute Structures

Furthermore, the design of the model holder of the present machine seems to contemplate only the subjection of the entire model to accelerations greater than the acceleration of gravity. Therefore, it is useful only for models which must be smaller in size than their prototypes. The investigation of minute structures, possibly even sub-microscopic or atomic, would require the testing of models larger than their prototypes. For such a purpose it would be necessary to accelerate them in fields less in magnitude than our gravitational field. Under such conditions unit masses would appear to have less than normal weight and there would be a tendency for the material of the model structure to have a lessened density.

To test a model in a centrifuge, it must be restrained in the model holder. If the points of restraint are as far distant from the center of rotation as is the neutral axis of the model, then the centrifugal effect tends to increase the density of the material of the model for all locations nearer than the outermost points of support. Of course, such an effect may be lessened where bending moments result in tensional strains.

I have proposed that models may be so attached to the model holder, by adhesives or the clamping of specially prepared forms of models, so that the points of restraint are at a less radius from the center of rotation than the points in the model which we wish to test in a reduced field of acceleration. Then the unit masses which have a greater radius of rotation will experience a rarefying effect which might be considered a decelerative (negative accelerative) field. In a horizontal centrifuge they would be subjected also to the gravitational vector at right angles, and that might be ignored where the rotational accelerations are relatively high.

I have further proposed a centrifuge which rotates the model in a vertical plane. When the rotative speed of such a machine is controlled so that the central acceleration of the model equals the acceleration of gravity, then the model passes through a field of zero acceleration at the point in its orbit furthest from the center of the earth. This effect is produced regardless of the method of restraint in the model holder. If the proper speed is determined for the radius of gyration of the model (that is, the radius of rotation of the center of mass, and therefore the neutral axis of a symmetrical form), then no force will be exerted upon the points of support of the model, no matter where they may be located. Of course, unit masses located at a lesser radius of rotation will be in an accelerative field, and those located at a greater radius of rotation will be in a decelerative field, at the point where the gravitational field is balanced out.

If stroboscopic observations are made at other points in the path of the model, the co-planar acceleration of gravity will change the direction and magnitude of the resulting force vector, except at the lowest point in the path of the model, when only the magnitude will change, as the acceleration of gravity is then algebraically additive to the rotational acceleration. If the model is observed at the midpoint between the top and bottom of its vertical orbit, then the acceleration of gravity is tangent to the model's circular path and so produces no radial force component.

The rotating model will receive cyclic variations in loading varied only by the acceleration of gravity, but thereby it will be subjected to what may well be called a "live" loading. The new method of restraint may also be employed to place the model in the so-called field of negative acceleration already mentioned.

With such new apparatus and methods prospective uses are opened in the field of pure physics; and then—

1. The behavior of prototypes of greatly reduced dimensions may be studied by the use of models of much larger sizes in weakened fields of force attained by the attachment of the nearest portion of the model to the center of rotation; and

2. A model may be studied in a zero field of force when it is rotated at a proper speed in a plane coincident with the gravitational lines of force.

Can Grinding Costs Be Reduced?

Betterment in Gravity Concentration Processes Offers Possibilities

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IN THE FIELD of gravity concentration two very distinct things are needed today. One is a better desliming classifier for use in closed-circuit grinding. The other is a highly efficient and cheap process that can be used to treat the deslimed product from the classifier to recover free mineral and to reject low-grade material that is not worth further grinding and concentration. A classifier and a concentration process adapted to these two needs could do much in reducing the prevailing high costs of grinding in sulphide milling. Moreover, they would be of great value in the concentration of non-sulphides, particularly of low-grade iron ores.

In the future, iron ores must be concentrated in increasingly large quantities, and they are low-priced materials that should not have to carry the present high costs of grinding. Further, because of the saving in the cost of sintering, the iron should be recovered in the coarse sizes as soon as the iron minerals are freed from the gangue minerals.

In this paper I shall take up the problem of better desliming classification and then discuss three common gravity processes that seem to have possibilities for further development that will suit them to what I shall call closed-circuit concentration, for want of a more explicative term.

To show the importance of better desliming classification, I refer to a paper entitled "Efficiency of Grinding Mills,"[1] by Gross and Zimmerley. The authors give data on two Western concentrators, showing that 90.5 per cent of the work done in the ball-mill circuits was expended in grinding the ore finer than necessary and was, therefore, useless. As the ore at the time of these tests was ground to 76 per cent minus 200 mesh, which is higher than average practice of today, this figure of 90.5 per cent of useless work is somewhat high for the average concentrator. But it shows plainly the order of magnitude of over-grinding and the seriousness of the problem it presents.

To give a concrete picture of what excessive over-grinding means from an economic standpoint, I have averaged the concentration costs as given in twenty-three Reports of Investigations[2] published by the United States Bureau of Mines, these being reports in which the necessary data are readily available. The average fineness of grinding for the concentrators discussed is 63 per cent minus 200 mesh. Average cost of concentration is 84.7c. per ton of raw ore. The average grinding cost is 26.4c. per ton, made up as follows: Power, 10.0c.; labor, 5.8c.; and supplies, 10.6c. Any reduction in over-grinding would, of course, effect a proportionate reduction in the cost of power and supplies and somewhat less than a proportionate reduction in the cost of labor. Thus, it seems to me that the development of a better desliming classifier offers great opportunity for reducing concentration costs.

Solution of this problem of developing a better desliming classifier, I believe, involves getting away from the present types of classifiers altogether. To show what I have in mind I refer to Fahrenwald's paper, "The Theory of Stratification and Its Application in Ore Dressing"[3] which is the best ever written on the subject and should be studied by every concentration man. For convenience, I am reproducing his Figs. 4a, 5a, and 6a in Figs. 1, 2, and 3, respectively. These show the different stratifications taking place in a mobile bed of particles of mixed sizes and specific gravities with various upward currents of water from zero velocity to a velocity that will give full teeter conditions in the mass of particles. The letters h_0, h_1, and h_2 on the water columns indicate the relative velocities of the upward currents of water used. The black circles represent the particles of high specific gravity and the white ones those of low specific gravity.

Fig. 1 gives the stratification for zero upward velocity of water. To this type belong most closed-circuit classifiers now in use. Zone 1, it will be seen, is composed of the finest particles of high specific gravity and Zone 2 of the coarse particles of high specific gravity mixed with the fine particles of low specific gravity. From these groupings of the particles one would expect present closed-circuit classifiers to return all of the fine material with the sands. However, the dewatering that accompanies the stratification modifies this separation to some extent, and only approximately enough fine particles to fill the voids between coarse particles are carried with the sands. That this return of fine particles results in excessive over-grinding has already been pointed out.

SUMMARY

1. The major proportion of grinding costs is incurred in over-grinding—that is, in grinding finer than necessary to liberate the valuable minerals from the gangue minerals.

2. To reduce over-grinding, a desliming classifier of the vertical-current type is needed. Some suggestions on the development of such an apparatus are given.

3. To eliminate liberated mineral and gangue at coarse sizes, improvements are needed in gravity processes. Tabling, launder processes, and jigging are discussed.

[1] Reports of Investigation No. 2952, U. S. Bureau of Mines (1929) 23 pp.

[2] Reports of Investigation, U. S. Bureau of Mines, Nos. 6285, 6343, 6353, 6357, 6364, 6404, 6408, 6411, 6430, 6433, 6467, 6479, 6489, 6497, 6508, 6550, 6573, 6587, 6590, 6605, 6619, 6706, 6742.

[3] *Mining and Metallurgy*, Vol. 7 (1926), pp. 437-443.

Fig. 2 shows the stratification that occurs when a small upward current of water is introduced. Arrangement of the particles differs from that in Fig. 1 in that the fine particles of both high and low specific gravities are at the top; otherwise, the groupings are unchanged. This type of stratification would obviously be ideal for desliming classification.

Fig. 3 shows the stratification occurring with an upward current of water just sufficient to hold the bed of particles in full teeter. This represents conditions in hindered-settling classification. This stratification, as will be seen, is very nearly the reverse of that in Fig. 1. Zone 1 in the new arrangement contains the large particles of high specific gravity, and Zone 2 the large particles of low specific gravity, together with the fine particles of high specific gravity. The fine particles of both specific gravities have overflowed the lip with the water. This type of classification obviously would also be suitable for desliming. However, since the intermediate type shown in Fig. 2 uses less water, it is the more desirable.

A classifier of the intermediate type, inasmuch as it uses only a small amount of water, must obviously have some mechanical agitation to aid in keeping the bed mobile, for, of course, mobility is fundamental to all types of separation. Is a classifier of this type available on the market? I know of none in ore dressing, but one, the cone washer, has been used in coal washing. This is an inverted cone with a central vertical shaft on which are mounted horizontal stirring arms. The stratification obtained with it is the combined result of the stirring from these arms and an upward current of water supplied at the bottom of the cone. The point to note is that neither the water nor the stirring is sufficient by itself to keep the bed mobile. As this apparatus embodies the proper type of stratification, it might be used as the starting point in developing a suitable classifier.

Another coal-washing machine, the Hydrotator, which belongs to the hindered-settling type (Fig. 3), also has possibilities as a desliming device. This classifier has a cylindrical tank and a central vertical shaft, which supports horizontal arms near the bottom. The shaft and the arms are hollow and deliver water to nozzles which are turned downward from the horizontal arms. As the shaft and arms revolve around the central shaft, the jets of water strike the bottom of the tank and rise vertically. In the hook-up of this apparatus that looks most promising for desliming classification, the intake of the circulating water pump is connected to the side of the tank below the level of the overflow lip. With this arrangement a comparatively thick pulp can be overflowed. This classifier also might serve as a starting point in development work on a classifier of the correct fundamental type for desliming.

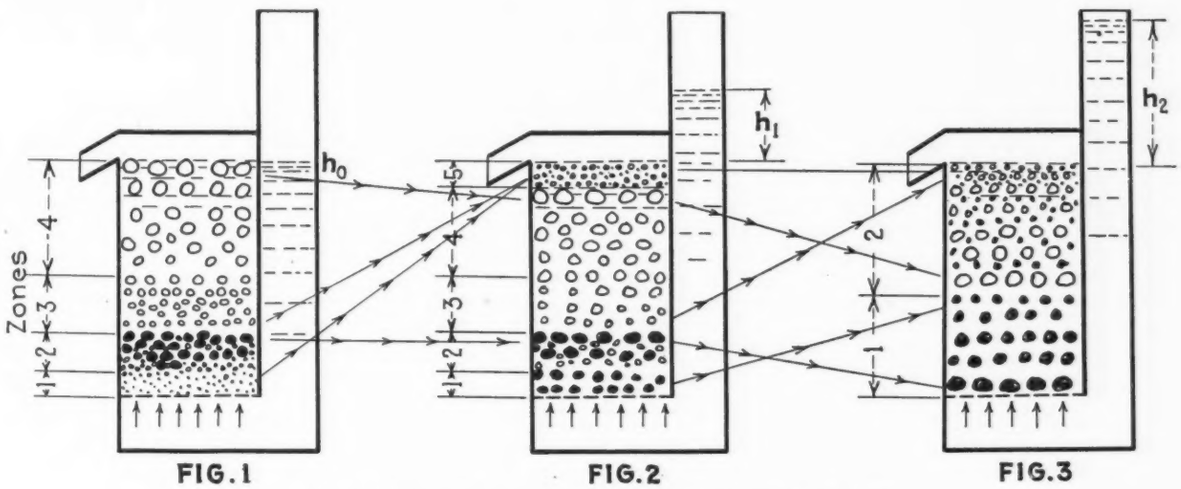
After the fundamental problem of applying the correct type of stratification is solved, mechanical details like dewatering the products and conveying them back to the ball mill will require little work, because present types of closed-circuit classifiers perform these two functions well.

Closed-Circuit Concentration

Improvement in desliming classification, because it would effect such large savings in the cost of concentration, presents an important problem. But losses due to over-grinding are by no means restricted to the fine stages of grinding. In many mills where the practice is to slime everything, a large percentage of the minerals is liberated at relatively coarse sizes. Under these conditions, an all-sliming practice is illogical; some process operated in closed circuit with the grinding mills should recover the valuable minerals and reject the gangue minerals as fast as they are freed from each other. Whether such a plan is economical in any given instance depends, of course, upon the proportion of free mineral in the ore after it has been deslimed and upon the cheapness of the concentration process. On each pass, only a portion of the ore can be eliminated as concentrate and tailing. The result is the saving of the cost of further grinding and of the cost of concentrating the eliminated material. If closed-circuit concentration is to be economical, these two savings combined must be more than the cost of passing all the material in the grinding circuit through the concentration process one time.

Rather than to attempt to develop a new process having the requisite low operating cost, I think the logical attack on this problem is to improve some existing gravity processes, a number of which have many unexplored possibilities for increased efficiency. In this paper I wish to take up three of the commonest of these, tabling, launder processes, and jigging, and to point out some promising development work that can be done to increase their efficiency.

Tabling—Tables have been extensively used in closed-circuit concentration. Usually they make a concentrate, a tailing, and a middling for return to the grinding mills. The most efficient way to use tables is in combination with hindered-settling classifiers. The classifiers are used to separate the material to be concentrated into a number of products, each of which is tabled separately. Zone 2 of Fig. 3 shows the general character of a classified product. It will be seen that the particles



Figs. 1-3—Diagrams showing different stratifications taking place in a mobile bed of particles of mixed sizes and specific gravities with various upward currents of water.

of high specific gravity are smaller than those of low specific gravity. When a product of this type is tabled, the result is a highly efficient separation, probably more efficient than any except that with a heavy liquid.

Against tables two objections have been advanced. One is the high loss in the tailing due to the tendency of sulphide minerals to float over with the water. Good desliming classification will, of course, obviate this objection by removing the extreme fines. The other is the low capacity of tables. I believe this latter is a valid objection, but I also believe that ore concentration men, in general, have an erroneous conception of the capacity of tables. A table is unique among concentration apparatus in that its maximum efficiency does not necessarily occur at a low tonnage. For the best work a table requires a certain load at all times. My observations have been that most ore tables are run far below their best operating capacities. Then again many ore concentration men do not classify the feed to their tables or do only a crude job. This results in a serious loss of capacity. A table[4] has been shown to have approximately twice as great capacity on a well-classified feed as it has on an unsized feed.

Table Capacity

At best tables, however, have a low capacity per square foot of floor space and should have further study designed to increase their capacity. The best approach to the solution of this problem lies in increasing the mobility of the bed of particles on the deck and thus increasing the rapidity of the separation. As the wash water is probably contributing at present all that can be expected of it, an increase in mobility involves increasing the amount of energy transmitted from the table deck to the mass of particles resting on it. Everyone who has tried rolling particles over a smooth surface by sliding that surface quickly back and forth knows that there is a speed at which maximum rolling of the particles occurs. This speed for tables should be carefully determined for various conditions. Also, the idea of increasing the amount of deck surface in contact with the mass of particles by using a large number of relatively high riffles on the deck[5] should have further study. Again, the effect of type of stroke upon the mobility should receive further study. The present table stroke combines the functions of producing mobility and of transporting the material longitudinally along the deck. If the published information is any criterion, almost no work has ever been done on this phase of tabling. And then the materials being used for deck coverings and for making the riffles should be studied as to their frictional properties, for obviously a high coefficient of friction is desirable. A study of these various factors and of others that will inevitably grow out of an investigation certainly gives promise of markedly increasing the capacity of tables.

A Problem

One important problem that arises in the concentration of most non-sulphides is the treatment of a feed that contains a large percentage of the mineral. Most apparatus used in ore dressing has been developed in sulphide milling, where the percentage of concentrates is small, and the devices employed simply do not have the necessary provision for removing materials of high density as fast as they stratify. Examples of this problem of treating materials containing large percentages of concentrates are fluorspars, phosphates, iron ores.

In tabling, little progress has been made on this problem. One logical approach to the solution is to develop table decks with large concentrate areas and relatively small tailing areas, the exact reverse of present types. Doubtless, tables will require other modifications to adapt them to such a feed of this character.

Launder Processes—Launder processes, such as the Rheolaveur, should be well adapted to any situation in closed-circuit concentration where the problem is one of rejecting a tailing from a deslimed feed, but where a high-grade concentrate is not essential. In these processes the material to be separated is fed into water flowing down a launder, and the product of high specific gravity settles to the bottom, whence it is drawn off through suitable openings; the product of low specific gravity overflows the end. The experience in coal washing, where these processes have been extensively used, is that the product of low specific gravity is very clean at the end of the primary launder, but that three or four re-treatments of the product of high specific gravity are necessary to produce a final product. Thus, in ore dressing this process is well suited to the rejection of a tailing, but not to the preparation of a high-grade concentrate. As the primary separation is cheap and, after all, most of the useless expense in grinding is in grinding gangue minerals, a cheap compact process involving one primary launder is worth serious consideration in ore concentration.

Fewer Re-treatments

Development work to improve launder processes should naturally be directed toward cutting down the number of re-treatments now necessary to yield the finished product of high specific gravity. One promising line of attack on this problem is to combine launder processes with vertical-current types of processes, such as classifiers and jigs, and to use them to clean up the low-grade concentrates from the primary launder. Another is to study the launder separation itself to determine the operating conditions that will render the flowing current most selective in its stratification of particles according to specific gravity. True, ideal conditions may obtain in a launder bed formed by the natural action of flowing water, but the chances are strongly against it. In a mass of particles moving along in a closely crowded condition one would expect a more complete separation than is now obtained in the primary launders of present-day commercial plants.

Jigging—Jigs have been and are being used in closed-circuit concentration. As in the case of tables, they usually make one or more finished products and a middling for the crushing or grinding mills. The special field for this process is on sizes above 14 to 20 mesh, though it will make a good separation on finer sizes at low tonnages.

Simplification

At Battelle Memorial Institute we have done a great deal of development work on jigging and have arrived at some simplifications of the numerous variables. The essential thing in jigging is the time-velocity curve of the water. A certain speed, length of stroke, amount of water, and type of stroke combine to give a certain curve. Naturally, many combinations give approximately the same curve and, hence, for practical purposes give the same separation. As experiments to determine the efficiency of the separation are necessary for only one curve of a given kind, the use of these curves greatly simplifies the work. We have been obtaining the data for these curves thus far by taking moving pictures of a float resting on the water in the jig. This float rises and falls in front of a scale, and with it we photograph a dial showing the point in the cycle where the picture is taken.

One important variable, however, is not covered by the time-velocity curve. It is the degree of mobility of the jig bed on the pulsion stroke; that is, the freedom of the particles to move with respect to one another. Comparative tests to determine the most efficient degree of mobility are hard to make because no reliable method of measurement is available. No one thing is needed more in fundamental work on jigging than a method of making this determination.

Development work on jigging in general should be directed to determine the types of time-velocity curves that give the most efficient separations for various conditions. In work of this character a jig of the type we are using at

[4] A.I.M.E. Coal Division (1930), pp. 250-271.

[5] U. S. Bureau of Mines, Bulletin 337 (1931), pp. 38-39.

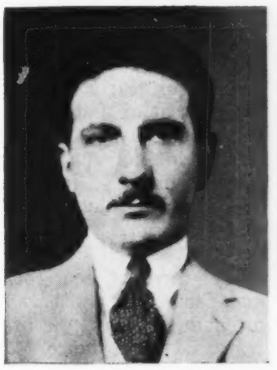
Battelle is helpful. This is a Baum jig, which uses compressed air in place of plungers to produce the pulsion strokes. On this jig is a special air valve that enables the operator to obtain with a few simple adjustments almost any type of time-velocity curve. The work we have done thus far in the study of these curves in relation to the efficiencies of the jig has proved a fruitful field. Some new types of strokes we have tried give as much as 30 per cent higher recovery than conventional types now in use.

The problem previously mentioned in connection with the discussion of tabling, that of handling a feed containing large percentages of mineral, also arises with jigs. On feeds of this character the conventional types of concentrate draws commonly used on ore jigs, such as the dam-and-seal or cup types, are hopelessly inadequate and simply limit the capacity of the jig to the capacity of the draws for discharging concentrates. One solution of this problem, which has been extensively used on coal jigs, is to install draws for the concentrates extending across the entire width of the jig compartment beneath the tailings overflow lip. If the slope of the screen is properly adjusted so that the concentrates will work forward rapidly, this type of draw should be effective.

Another problem that arises in nonsulphide concentration is the automatic control of the withdrawal of concentrates. The old idea that a clean concentrate and a clean tailing cannot be made in one pass over a multiple-cell jig has been exploded by the coal man. In this particular the secret is good operating conditions coupled with automatic control of the jig. The float control now in use on a number of the better coal jigs can be adopted bodily on ore jigs to advantage.

Flotation's Future

Beset With Difficult Problems



The Art at Maturity But Not Yet Static

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GEORGE SCATCHARD, professor of physical chemistry in the Massachusetts Institute of Technology, speaks as follows on the twenty-first birthday of the inter-ionic theory of electrolyte solutions: "For eleven years the new theory was a feeble and awkward child. Its father thought well of it, but no one else paid it much attention except on one occasion, and then the attention paid was far from favorable. Almost every child passes through a period of rather obnoxious publicity-seeking when it first discovers that certain words can shock the adult ear . . . In its sixth year (our theory) passed through what we may call the 'swear-word episode.' . . . Then . . . there was a sudden change from the feeble, awkward child to an elegant, graceful, and powerful youth."

What Professor Scatchard says so pleasingly of the inter-ionic theory might likewise be said of the froth-flotation process, except that the development of that process is somewhat more advanced, it having reached its twenty-eighth birthday, if birth is reckoned from U. S. Patent 835,120, issued in 1905. As a result, the problems that face the practitioner and the student of the flotation art are not the relatively simple problems of youth but the more complex and involved issues of early maturity. Some of these problems require much imagination, others much patience, still others a keen appreciation of economic honesty—all much work even for an approximate solution.

So as to facilitate a bird's-eye view of the whole field, it appears desirable to classify the problems into several more or less artificial divisions as follows:

1. Problems relating to actual mill operation.
2. Problems relating to efficiency of practical operations.
3. Problems relating to the theoretical development of the art.
4. Problems relating to expansion of the art into new fields.

Mill Operation Data

The great majority of operators of experience are probably securing acceptable if not, indeed, good results under the conditions which control their operations. This has resulted largely after a blind cut-and-try search for the best practice. The efforts involved have cost much time and money; yet because of the difficulty involved in communicating practical experience to others, the splendid results obtained on each ore are generally retained by the operator or operators who have made the expenditure of effort, and they do not benefit the profession as a whole. In other words, there is no *systematic clearing house for practical data* in which results, expressed as metallurgical efficiency, are related to the many operating variables, such as depth of bubble column, bubble size at bottom and top of bubble column, pulp temperature, pulp density, and others. It would seem worth while to quantify data of this character, and to gather them from all possible sources, in order to be able to analyze them critically, for example, by the statistical method of Taggart, or by some other method. Such an extended study as is considered here would certainly reduce significantly the period of trial-and-error required under the present conditions in tackling a new problem. Improved and simplified operation would follow the dissemination of significantly interpreted operating data.

Again, the great majority of operators have preferences for one type of machine or other. That so few trustworthy and impartial data on this subject are extant is amazing. Figures that are available are often intended to support sales talks; other data are incomplete from a comparative viewpoint at least, having been obtained by observers with a limited field of experience. A comprehensive, honest, and impartial survey of flotation-machine types would no doubt ascertain which machine is best for each purpose, and it may suggest new designs having

particular advantages. In our future economy, in which much smaller quantities of dollars and pennies will be featured, a more precise bulk of information will be sorely needed.

On the subject of flowsheets—that is, arrangement of machines, place of addition of reagents and related detail—our progress seems to some extent to parallel that in the suit-and-cloak trade: certain patterns become fashionable in turn, because a successful model displays them. This view should not be accepted too literally, but there is enough truth in it to show that here again an inquisitive mind or two may help decide which flowsheet fits best each ore, without the costly trial on plant scale at the beginning.

Improvement in Efficiency

One of the outstanding problems in need of solution for the improvement in metallurgical efficiency of practical operations is that of treatment of particles of colloidal or near-colloidal size. Although the content of material of this fineness in present-day pulps is still relatively small, the current tendency to grind finer in order to increase liberation is making the solution of the problem more desirable. Also, since a major part of the present-day metal losses is in the form of near-colloidal and colloidal material, and because margins of profit are smaller, the problem assumes enhanced importance. Much experimentation is no doubt required to bring this problem to a working solution.

The recent trend to finer grinding of locked particles by the scheme of concentrate or middling regrinds continues to assert itself. Much, however, remains to be done to produce concentrates that are mineralogically as pure as the tailings currently made. For instance, the tailing made by a leading copper concentrator contains only 0.3 per cent in copper minerals (0.15 per cent copper), whereas the concentrate contains 45 per cent of minerals barren of copper (27 per cent copper). In other words, the tailing is 150 times cleaner than the concentrate! Improvement on this score will come through more extensive application of the microscope, through more delicate chemical control, and in many cases through the invention of new pyro- or hydro-metallurgical methods for extracting metals from pure or nearly pure concentrates.

Improvement in metallurgical efficiency in the field of flotation of precious-metal ores is, in many cases, the crying need of the present day, even though excellent results have been obtained to date, as may be seen by perusing some of the recent issues of this journal. Here, again, careful chemical control in floating, and much microscope work of great delicacy on polished sections of flotation products, will be necessary, along with a marshaling of known facts concerning gold and silver flotation.

The flotation of coals has given some promise, but the results have been disappointing in this country. What seems necessary besides education of the consumer to the use of a higher-grade fuel at a slightly increased price is fundamental research to determine how to improve the grade of the coal sufficiently by floating to produce a fuel that is nearly ash-free; also, methods for dewatering the flotation concentrates much more completely.

Bubbles

Non-metallics can be concentrated by flotation, as is well known, but the application of the art in that field has lagged behind, largely because the problems in non-metallic treatment have not come to the attention of trained flotation investigators. Here, again, the field is not standardized and much experimentation is necessary.

Fundamental Research

Fundamental flotation research has reached the stage where it deals almost exclusively with organic and physical chemistry. One of the principal problems in need of solution is that dealing with the mechanism of collector reaction with sulphide minerals. Despite the search already made in this field, it is increasingly clear that we do not as yet have a satisfactory answer to the query: "How do collectors attach themselves to sulphide minerals so as to float them?" This search is handicapped by the lack of knowledge concerning the chemistry of collecting agents. These are unusual organic substances forming compounds with metals, so that a whole new chemistry has to be evolved, which pertains likewise to the organic and inorganic fields of chemical study. This new chemistry must be built up from the ground—a long and difficult task.

A lesser problem, but one that may have practical implications of some consequence, is that relating to the effect on frothers of changes in variables such as in pH, added salts, and presence of solids in pulp. Precise measurements in this field are highly desirable.

Developments in flotation have been so rapid that one of the essential factors at play—namely, the chemical effects of dissolved gases—has received scant attention. Recent theories have shown that gases are of extreme importance in many instances. It is not unlikely that control of flotation can be exercised through control of the gases.

The contact-angle determinations recently made in Australian laboratories promise to tie up the chemical studies conducted in this country with the practical effects of reagents observed everywhere. This coordination will result from a determination in a scientific manner of the physical effects of additions of the reagents to simple flotation systems. In this field much can be done, no doubt, to develop more precise methods for the determination of contact angles.

A new theory of flotation has been ushered in by Professor Ostwald's speculations. If it can be substantiated by experimentation it will no doubt mark the initiation of a new era in flotation thinking, research, and practice.

Mathematical analysis of matters pertaining to particle shape, particle size, bubble size, and probability of encounter of particles with bubbles should be of assistance in interpreting some of the puzzling phenomena encountered. It should make possible in a quantitative way the study of many things now viewed qualitatively only.

A re-investigation of the relationship of flotation to flocculation is also needed. This problem was studied in England ten to twenty years ago, but with the introduction of non-oleaginous collectors, which as we know are characterized by a striking ability to float granular material, attention has drifted to other matters. A re-investigation of flotation-flocculation relationships should assist in solving the treatment by flotation of colloidal material.

The past year has seen continued expansion of flotation in the treatment of precious-metal ores. This develo ment will continue, however, not so much in competition with cyanidation and amalgamation as in collaboration with them. The keynote of increased application of the art will not be antagonism to older or established methods so much as cooperation with them.

Continued expansion, perhaps at a slow rate, is indicated for the field of treatment of ordinary (polar) nonmetallic minerals.

Great advances, perhaps not immediately, appear in store in the field of coal cleaning. The problems here are so vast, numerous, and complex that many years will have to be devoted to the study of coal mineralogy. Several

more years may elapse before routine application on a large scale is made of the practical discoveries in the fields of coal mineralogy and processing, but the game is worth the candle!

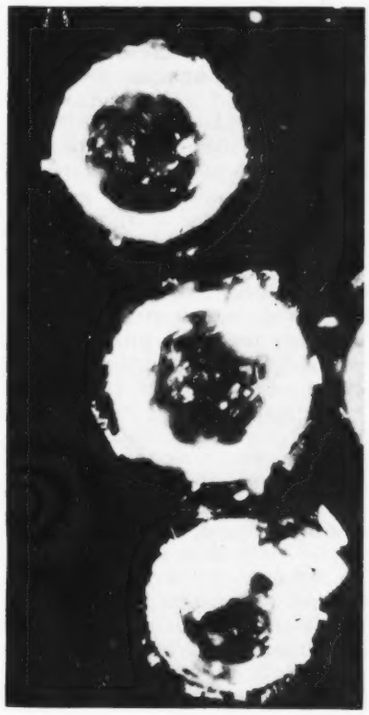
Extension of the use of flotation to new fields is also possible, if not probable. Among these are:

1. Concentration of beach sands and of placer deposits.
2. Direct production by flotation of finished products not requiring smelting —namely, paint pigments.
3. Concentration of intermediate products obtained during smelting—for example, of converter slag.
4. Combination with leaching in the treatment of some oxidized ores.
5. De-oiling of oil sands.
6. Sewage treatment.
7. Chemical industry in general.

This list is by no means complete but is merely indicative of the possibilities of the art. Some of these extensions may fail to materialize, and others, not mentioned here, will bloom with vigor.

From the rather formidable list of problems facing the flotation operator and investigator, it is patent that the art has not reached a static condition, but is rather in a state of active development. This development, however, is one involving the solution of many difficult problems, each of limited scope, rather than one involving the solution of one or two problems of overwhelming importance. This is why the conviction may be reasserted that the problems now facing the art are the complex and subtle problems of early maturity—not those of boisterous youth.

Bubbles coated with galena particles
Courtesy of A. F. Taggart



Scientific Research

Its Possible Future Bearing on the Non-Ferrous Metal Industries

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TO THE non-ferrous metal industries the onward march of science is becoming increasingly important, the last fifteen years furnishing an example of progress unparalleled in human history. The tremendous outburst of energy brought forth by the World War, the ingenuity called upon to meet the many emergencies arising from lack of essential materials, the high degree of organization, and the generous supply of funds made available, far outweighed the waste and destruction of materials occasioned by the cataclysm, and hurled technique and science ahead at greatly accelerated speed as soon as all energies could again be turned to peaceful pursuits. Not even the worst depression ever experienced in the economic life of the world has been able to check this forward march of science.

Fortunately, the development has been more on the type of an evolution than that of a revolution, although the rate of speed may well justify the use of the latter term. In the investigations concerning the nature of matter, probably the most important scientific research of the day, the fundamental principle of Dalton's century-old atomic theory has been found correct, although the modern conception of the nature of the atom itself is probably far beyond any imagination of the venerable philosopher. Through this study of the structure of matter—or physical force or energy into which matter has now resolved itself—every branch of chemistry and physics has been greatly benefited. A definite connection has been found between atomic structure and chemical properties; the mysteries of valence and chemical affinity have been rationally explained; a better and more complete picture of the periodic system has been presented; and the transmutation of the elements has become an accomplished fact. The possibility of commercial exploitation of the last-named phenomenon, and of tapping the immense reservoirs of energy locked up in the atom, quantities of energy far beyond present human conceptions, may be scoffed at today, but these possibilities are indeed a challenge. History certainly bears out the concept that the realization of the existence of a problem almost invariably is equivalent to a prophecy of its solution.

Rôle of the Chemist

In his study of the reactions in the laboratory of Nature, the chemist has also accomplished astounding feats. Nature, proverbially slow and wasteful, rarely comes up to the rigid and exacting standards of modern science. Synthesis of many complex organic compounds has been accomplished in recent years, and material civilization has been correspondingly enriched. Artificial fibers, solvents, plastics, and lacquers are some of the new products thus made available to man. Increasing understanding of catalytic action and ability to operate chemical processes at temperatures and pressures far above anything dreamed of a few years ago have opened the field for practical utilization of many new reactions. Instead of a threatening nitrogen famine freely predicted at the turn of the century, chemical industry is now faced with the problem of creating new demands for an abundant and cheap supply of fixed nitrogen; and the possibility of any scarcity of liquid fuels has become remote, as practical hydrogenation processes are already within our grasp. With the revolutionary changes in transportation now in evidence, the latter fact may take on added signification.

Modern studies of the structure of matter have also proved highly fruitful to the physicist, by throwing entirely

new light on the nature of electricity, and through the discoveries of the many new types of rays. The application which appeals most strongly to the imagination is radio transmission, which has already wrought tremendous changes in the lives of individuals and nations, although no doubt can be held that far greater things are yet to come. Improved filaments, atomic-hydrogen welding, and a diversified utilization of electronics are other important results. The vacuum tube and the photo-electric cell are constantly being put to new uses which bring promise of a day when our industrial workers shall be elevated from being mere servants of the machine to intelligent supervisors of highly organized units of machinery operating almost completely automatically.

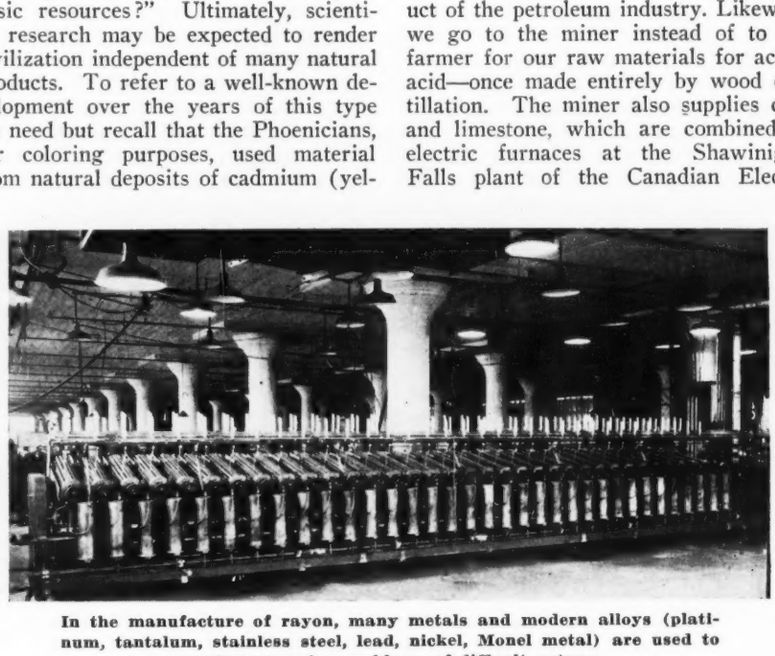
New Uses for Common Metals

In the production and utilization of non-ferrous metals this advance in scientific achievement is being accompanied by some striking developments. Low-cost metals are being substituted for those generally used for certain purposes, largely as the result of the addition of small amounts of alloying constituents that materially enhance the original properties of these metals. Improved methods of production, providing lower extraction costs, are giving impetus to this trend. New uses for many metals, particularly for the more uncommon ones, are being rapidly developed. The outlook for any non-ferrous metal may therefore be said to include under the rapid advance of scientific research the prospect of marked change in utilization or production. Some of the evidence available, indicative of the changing status of several of the non-ferrous metals, is cited in the paragraphs that follow.

By the application of new methods, the recovery of aluminum on a commercial scale from ores other than bauxite may be expected within a comparatively short time. Research to this end is progressing in an encouraging manner in several countries, particularly in Norway, where a combination process is understood to have been evolved that utilizes iron ore and clay to produce an alumina-containing slag, from which aluminum is subsequently recovered. As soon as such processes are perfected, the price of aluminum will decrease, and utilization of the metal will undoubtedly expand sharply, probably at the expense of other metals. An attendant development then will be a decline in the value of bauxite mining properties.

What's Around the Corner?

This possibility of a sharp decrease in the value of a natural resource, such as a bauxite deposit, merits a digression here to allude briefly to changing concepts concerning the conservation of such resources. In this connection Zimmerman[1] has said: "Changes in the arts made by injecting a highly dynamic element into the problem of conservation render the formulation of hard and fast rules difficult. Who dares to predict the future needs for forest products when the technique of scrap recovery is rapidly advancing, when science is only beginning to study seriously the possibilities of utilizing such agricultural products as wheat straw, cornstalks, and other sources of cellulose; when the possibility of turning common clay into aluminum looms on the horizon, and innumerable other improvements promise to throw an entirely new light upon the need and availability of basic resources?" Ultimately, scientific research may be expected to render civilization independent of many natural products. To refer to a well-known development over the years of this type we need but recall that the Phoenicians, for coloring purposes, used material from natural deposits of cadmium (yellow), red sulphide of mercury, and iron oxide (reds), whereas the paint industry today employs manufactured pigments.



In the manufacture of rayon, many metals and modern alloys (platinum, tantalum, stainless steel, lead, nickel, Monel metal) are used to combat corrosion problems of difficult nature.

Present Crudities

In like manner, it will not be long before an audience will listen with a smile to an account of how thousands of worms were carefully nurtured on mulberry leaves in specially constructed houses, how these worms were induced to spin cocoons, and how these cocoons were unwrapped, the thread forming the basis of our entire silk industry. Similarly, the next generations will be amused when they hear that men could not play billiards unless someone went to Asia or Africa and brought back with him sufficient elephant tusks out of which to manufacture the billiard balls.

Millions of bushels of wheat and millions of gallons of milk are consumed every year in feeding a nation such as ours. The actual energy finally turned into blood and bone is ridiculously small when compared with the vast amount of energy expended in producing these staple food products. It will not be long before civilization will be independent of sources of food energy supply such as grain and milk. It is not difficult to prophesy events such as these, since beginnings are already at hand. Thus, we are no longer entirely dependent upon grain and other agricultural raw materials to produce one of our most important commodities—namely, ethyl alcohol. The last few years have demonstrated conclusively that this important solvent and "stimulant" has become a commercial byproduct of the petroleum industry. Likewise, we go to the miner instead of to the farmer for our raw materials for acetic acid—once made entirely by wood distillation. The miner also supplies coal and limestone, which are combined in electric furnaces at the Shawinigan Falls plant of the Canadian Electro Products Company to form calcium carbide, and from carbide we get acetylene, from acetylene, acetaldehyde, and from that acetic acid and acetone. At the recent Chemical Show our neighbor, *Chemical and Metallurgical Engineering,* bestowed upon Carbide & Carbon Chemicals Corporation the award of merit in recognition of its meritorious contribution to the advance of the industry and profession. This company has built up a vast, new synthetic chemical industry, one of the chief plants being located at Charleston, W. Va., where petroleum hydrocarbons are converted into alcohol and other solvents.

High-Temperature Products

We look to the electric furnace, that made this new industry possible, as a most valuable tool which the older generation unfortunately never possessed. With this new, high-temperature apparatus at our command, reactions can be brought about which our forefathers assumed would take place only in the sun. Whereas the engineer in the past has largely directed his efforts in breaking down complexes to

[1]Zimmerman, Erich W.: "World Resources and Industries." Harper & Bros., 1933.

simpler products, thus starting out with complex coal tar or complex sulphide minerals and getting the final relatively simple components, the tendency of the new era is to start out with two or more relatively simple elements or compounds, and, with the aid of electrical energy, bring about combinations resulting in products demanding new uses, new applications. For 30 years efforts have been made to produce pure tantalum metal. A few experiments were made on the development of making tantalum alloys. Only recently, however, have we realized that possibly the biggest application of tantalum will be in tantalum compounds rather than in the pure metallic product. Thus, tantalum carbide has found wide application in the cutting industry. Whereas our research in the past has been directed mainly toward producing pure, simple products, our researches of the immediate future are directed more toward taking the mining engineers' relatively simple elements or compounds and combining these into new and considerably more valuable products.

Titanium

Another pretty illustration is the history of the mining and metallurgy of titanium. For a good many years we have concentrated our efforts in developing the best and cheapest methods of recovering titanium metal from its minerals, ilmenite and rutile. Today the industry is concerned largely with titanium compounds. Thus, according to F. H. Driggs,[2] titanium pigment manufacturers have been operating at practically full capacity during the recent, awful years of the depression, and the imports of ilmenite ore were the highest on record from the standpoint of both tonnage and value. Titanium pigments have become serious competitors of lead pigments. Investigations now under way promise to broaden the titanium compound field even far beyond that now covered by the paint industry.

In the non-ferrous industry the trend of recent years and the indications for the immediate future look toward the development of markets for so-called impurities heretofore buried in the dump. A typical illustration is tellurium of the copper industry. The output of tellurium during the four years of the depression has been about fourfold that of the prosperity years, 1929 and those immediately preceding. This increase is due largely to the discovery on the part of U. C. Tainton that small additions of tellurium to the zinc electrolyte facilitate the elimination of the very objectionable cobalt impurity. F. C. Mathers, S. Skowronski, and others have electrodeposited tellurium plates a quarter of an inch thick and more. What use may we find for tellurium-plated metals?

The electrolytic copper industry is disposing of all of its selenium, largely to the glass industry, selenium forming the basis of the well-known red glass of the traffic signals. Not many years ago the only commercial application of selenium was for the selenium photocell.

Substitutes for Copper

One question naturally arises: "May the copper industries continue to count upon the electrical manufacturers as their main outlet?" Looking over the consumption figures for the last four or five years, the distribution runs about 60 to 70 per cent of copper in electrical apparatus and appliances. Are we justified in continuing our assumption and belief that copper will always be the basic metal of the electrical industries? Frankly, we have had too many instances in the past where new discoveries have completely changed the "essential basic materials." Thus, for example, in the communication field, in many cases it has meant the complete elimination of the telegraph wire. With wider use of better-conducting metals such as sodium, are we not justified in assuming that copper will not continue to be the basic metal of the electrical industries? If that time comes, what will be the main outlet for the product of our copper mines?

As in the copper industry, so likewise in the zinc industry. The by-product metals have become a very prominent item in the total output of zinc plants. Cadmium, one of the main byproducts, is now looked upon as "a regular member" of the family of non-ferrous metals, but there are indium, germanium, and gallium, anxiously awaiting a market and use. Experiments have been made on the electrodeposition of indium, with promising results, notably on silver. Germanium appears to be available in quantities much larger than we had ever anticipated. Gallium emits electrons at lower temperatures than other metals and offers valuable applications in this field. Aside from the utilization of the three metals, gallium, germanium, and indium, as such, the biggest promise of the future appears to lie in compounds of these three metals, heretofore looked upon as outsiders. Again we have to train our minds to look for applications not merely of the metals or alloys as such, but of compounds of these three new-comers in the industrial field. Who knows whether or not a compound of one or the other of these three metals will make a dye for cottons and silks that will not bleach out in the sun? And few dyes there are today that will withstand the action of the ultra-violet rays. Our dye industry has taken it for granted, more or less, that dyes for fabrics must be composed primarily of carbon, hydrogen, and oxygen. To us it seems that the best outlook for fast and wash-proof dyes will be in those of mineral origin or composition. It is needless to mention that the very best blue we have today, universally used to offset the yellow cast due to iron, is artificial lapis lazuli, or ultramarine. No satisfactory explanation has ever been advanced to account for the beautiful blue of ultramarine. May we not safely assume that other mineral compounds may be developed just as permanent, as far as the ultra-violet rays are concerned, as ultramarine?

We have studied the composition of the earth's crust. We know that aluminum and magnesium are by far more abundant than most of the other metals. A very significant demonstration of the valuable physical properties of magnesium and its alloys was given recently when the gondola of the Settle stratosphere balloon was built of magnesium alloy and withstood the very high pressures to which it was exposed. We of the older school find it difficult to look upon a metal such as magnesium as being at all in a class with a metal like steel on the basis of physical and mechanical properties. We are too prone to assume that an alloy of magnesium cannot be produced which will have mechanical properties anywhere near those of our favorite old steels. The remarkable fatigue endurance of Dow metal, composed of 95 per cent magnesium, is ever and anon a big surprise to our ferrous metallurgists.

Possible Achievement

Briefly, then, what may we expect in the next few years in the mining and metallurgical industries? To begin with, I feel justified in predicting that the mineral industries are going to invade fields from which they have been heretofore almost entirely excluded. Thus, as I have said, we expect important developments in sun-proof dyes having a mineral basis. We must be fully prepared to appreciate that the main consumption of some of our mining products, whether it be copper or zinc or lead or tin, will not be primarily as metals but as compounds. We find in the earth's crust a vast hoard of compounds, some highly resistant to high temperatures, others highly resistant to the action of water, others showing marked resistance to abrasion. We must get away from the belief that these compounds which we naturally find in the crust of the earth are the only ones possible. Quite the contrary! With the facilities at our disposal today we can, at very high temperatures, or under the influence of very powerful electric discharges, or through the action of powerful chemical and physical means, bring about reactions which even nature has not produced in the past.

[2]Mineral Industry 41, 517 (1932)

Silicosis Compensation

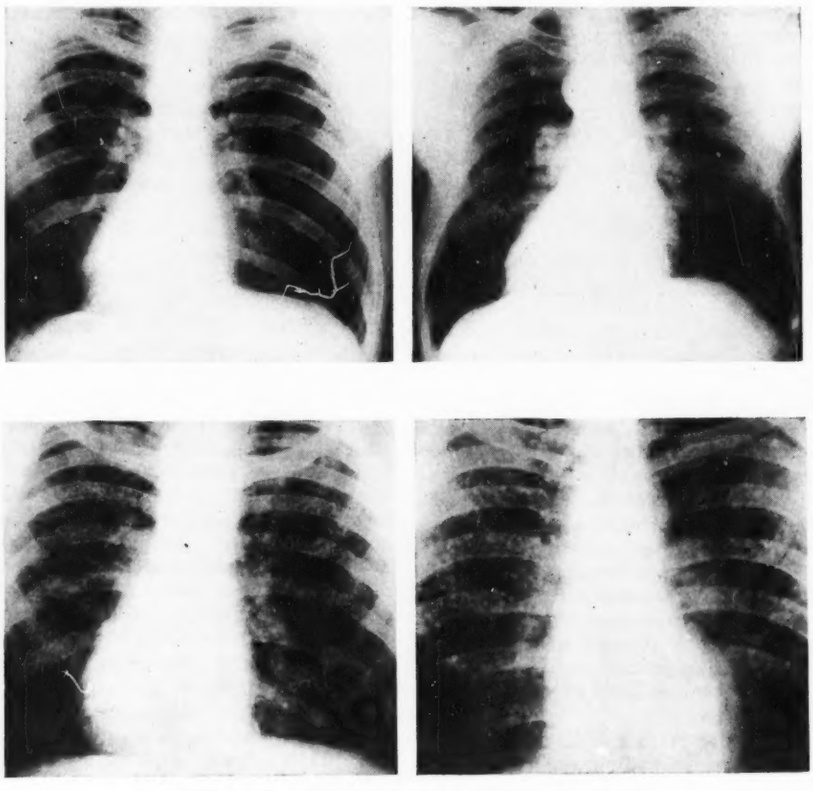
Its Import for the Mining Industry

H. D. Keiser

Associate Editor

RECOGNITION of the menace that dust diseases, particularly silicosis, hold for the industrial worker grows apace. So rapid, in fact, has this growth been that recent developments, international and national, would seem to be portentous. For instance, the 1934 session of the International Labor Conference, to be held at Geneva in May, will probably adopt an extended schedule of compensable occupational diseases that includes silicosis.[1] "In more than one industry today," to quote from a recent issue of the leading publication circulating among the members of the medical profession,[2] "the most important slogan in the 'New Deal,' from the standpoint of welfare defined in terms of health and comfort, would be: Stop the Dust!" Further, D. Harrington, chief of the health and safety branch of the U. S. Bureau of Mines, stated recently[3], " . . . There is absolutely no doubt that dust diseases are directly responsible for the death of several hundred underground workers annually in the United States and indirectly responsible for the death or disability of several thousand others. . . . Usually in the regions most afflicted a concerted effort is made toward minimizing the dangerous conditions. In fact, 'pussy-footing' about dust disease is now and has for many years been largely the rule."

In the light of the foregoing facts the seriousness of the dust menace is apparent. A thorough understanding of its major features on the part of the mining industry in the United States would seem advisable, and to this end *Engineering and Mining Journal* undertakes here and in two subsequent articles to present a brief summary of the more important factual material available. Space limitations preclude detailed consideration of many phases of the subject, but references will be made to existing literature where additional data may be had. In this connection attention is directed to an excellent bibliography of more than 150 items that is appended to the paper by D. Harrington, to which reference has already been made.



Normal and silicotic chests as revealed by the X-ray

Upper left—Normal chest. Upper right—First stage silicosis. Lower left—Second stage silicosis. Lower right—Third stage silicosis. Courtesy U. S. Public Health Service.

This first article will discuss the legal or compensation features of silicosis and other pneumoconioses (the inclusive medical term for diseases of the lungs caused by dust). Four distinct methods[4] prevail whereby these diseases are included among those listed as compensable in the laws of various countries, states, and provinces throughout the world. These methods, with the names of the countries, states, and provinces employing each, follow:

1. By implication from the general wording of the workmen's compensation act regarding injuries covered. Certain states of United States and South and Central America.

2. By listing in a schedule the compensable occupational diseases covered by the act. Several countries, states, or provinces in Europe, Latin America, Australia, and Canada.

3. By a clause in the act providing for special schemes to be drawn up for the compensation of silicosis. England and New South Wales.

[1] Report V, International Labor Conference, eighteenth session, Geneva, 1934, "Workmen's Compensation for Occupational Diseases." International Labor Office, Geneva, 1933.

[2] *Journal of the American Medical Association*, Sept. 9, 1933.

[3] "Occupational Disease Hazard of Silicosis in Construction Operations and Its Prevention," by D. Harrington, Chief, Health and Safety Branch, U. S. Bureau of Mines, Washington, D. C. Paper presented before the Construction Section, National Safety Council, Oct. 2, 1933, Chicago, Ill.

[4] "Workmen's Compensation for Silicosis," Report of the Committee on Pneumoconioses of the American Public Health Association, October, 1933. Printed by the Association of Casualty and Surety Executives, New York, N. Y. Contains bibliography of silicosis legislation.

LEGISLATIVE PROVISIONS FOR COMPENSATION FOR SILICOSIS AND OTHER DISEASES OF THE LUNGS CAUSED BY DUST

(From "Workmen's Compensation for Silicosis," report of the Committee on Pneumoconioses of American Public Health Association; Printed by the Association of Casualty and Surety Executives)

Country or State	*TYPE OF LAW*				*Description of Diseases of the Lungs Listed as Due to Dust Covered in the Law*	*Description of Occupation in which Exposure Occurs—Listed as Covered in the Law*
	a General Coverage of All Injuries of Occupational Origin, Presumably Including Silicosis	*b Listed in Schedule of Compensable Occupational Diseases*	*c Provision for Special Schemes for Compensation.*	*d Special Acts*		
AUSTRALIA Commonwealth of Australia and Northern Territory		1930 1931			Pneumoconiosis	Quarrying or stone crushing or cutting
New South Wales	1926 but diseases due to silica dust specifically exempted		1920 Silicosis Act (1926 amendment) 1927 Scheme for Cumberland District (amendments 1927 and 1929)	1920 Broken Hill Mines Act and Scheme amended 1927, 1929	Silicosis or silicosis accompanied by tuberculosis Pneumoconiosis and/or tuberculosis	Stonemasons, Quarrymen, Rock choppers, Sewer miners } employed 300 days working sandstone in Cumberland County district Broken Hill Mines, Yancowinna County
Queensland		1916-23 and 1925 1926, 1929			Silicosis of lungs Miners' phthisis Pneumoconiosis Pulmonary tuberculosis	Mining or quarrying or stone crushing or cutting In employment 300-500 days
Tasmania				Miners' (Occupational Disease) Act 1929 Relief Fund	Silicosis Pneumoconiosis Fibrosis	Mining In employment 5 years
Western Australia		1912 with amendments to 1924; 1925 and 1927		Miners' Phthisis Act 1923, amended 1925 and 1929; Mine Workers' Relief Act 1932	Silicosis Miners' phthisis Silicosis Tuberculosis	Mining or quarrying or stone crushing or cutting Any person occupied or employed in mining operations on, in, or about any mine
NEW ZEALAND				Pensions Act 1926 and amendment 1932	Miners' phthisis	Mining
CANADA Alberta		1918 and 1928			Pneumoconiosis which shall be deemed to be: Silicosis Siderosis Lithosis	Quarrying, cutting, crushing, grinding, or polishing of stone or grinding or polishing of metal. Mining (exposure of 1 year)
Ontario		1914, and 1925-1929 and 1932			Stoneworkers' or grinders' phthisis (1925) Pneumoconiosis 1926 Silicosis (1926)	Quarrying, cutting, crushing, grinding or polishing of stone or grinding or polishing of metal. (after 3 years' exposure) Mining (if employed in exposure to silica dust for at least 5 years previous to disablement)
Saskatchewan		1929			Miners' phthisis Silicosis Stoneworkers' or grinders' phthisis Pneumoconiosis	Mining (if employed in exposure to silica dust for at least 5 years preceding disablement) Quarrying, cutting, crushing, grinding or polishing of stone or grinding or polishing of metal
UNION OF SOUTH AFRICA				1925 amended 1930	Simple silicosis Tuberculosis with silicosis Simple tuberculosis	Underground miners who have worked in scheduled mines on the Witwatersrand for a period of 2 years or who can satisfy medical board that they have contracted silicosis in such a mine

4. By special act. Switzerland, Union of South Africa, New South Wales, Tasmania, Western Australia, New Zealand.

In the United States[4] workmen's compensation laws covering occupational disease exist in only eleven of the states, three territories, and the District of Columbia, none of which specifically mentions silicosis or other pneumoconioses. Five of these states—namely, Illinois, Minnesota, New Jersey, New York, and Ohio—and also Puerto Rico have scheduled such occupational diseases as shall be considered compensable and have not listed silicosis. Therefore, silicosis and allied diseases are definitely not compensable in those states at present. In the remaining six states, two territories, and the District of Columbia, the compensation laws bring in occupational diseases under a general coverage or through interpretation of the words "personal injuries arising out of the employment" unqualified by any requirement that such injury shall be "by accident." Under this type of law silicosis might be considered a compensable occupational disease in California, Connecticut, District of Columbia, Hawaii, Massachusetts, Missouri (occupational diseases covered optionally under the workmen's compensation act by mutual consent of employer and employee), North Dakota, Philippine Islands, and Wisconsin. The United States Civil Employees and the Federal Longshoremen's and Harbor Workers' Acts are of similar type. In fact, silicosis, especially silicosis accompanied by tuberculosis, has for some years been the subject of compensation awards in California, Connecticut, Massachusetts, and Wisconsin, but in the three states last named, at least, upon terms and conditions not yet definitely established.

Status Abroad

Silicosis and other pneumoconioses are specifically scheduled[4] in the workmen's compensation act as compensable occupational diseases, usually when contracted in certain specified occupations, in Bulgaria, Czechoslovakia, Denmark, Germany, Russia, Sweden, Argentina, Bolivia, Brazil, Chile, Mexico, Commonwealth of Australia, Northern Territory, Queensland, and Western Australia, and in Alberta, Ontario, and Saskatchewan. In Ontario and Saskatchewan, however, special provisions restricting the conditions under which silicosis shall be considered compensable are incorporated into the act, whereas Western Australia has both listed pneumoconiosis and miners' phthisis in the schedule and maintained an older miners' phthisis act and relief fund act for those not now covered under the compensation act. Quebec formerly had a silicosis act similar to that of Ontario, but repealed it in April, 1933. Switzerland, England, South Africa, New South Wales, Tasmania, and New Zealand have arranged for the compensation of silicosis by means of separate special acts or funds or special provisions under the workmen's compensation acts applying to certain industries or certain districts.

From the foregoing, the relative status of silicosis compensation legislation in the United States, compared with that in much of the rest of the world, is evident. A record of existing silicosis legislation in three important mineral-producing countries—Australia, Canada, South Africa—is presented in the accompanying table.

What is the cost of silicosis compensation to the mining industry? On the Witwatersrand in South Africa,[5] for the year April 1, 1931, to March 31, 1932, total compensation expenditures for European miners was £716,107; total compensation expenditures for natives was £58,031; total administrative expenses of the Miners' Phthisis Board, Miners' Phthisis Medical Bureau, and Medical Board of Appeal were £50,855—a grand total expenditure of £824,993. During this period[6] 32,627,720 tons of ore was milled and 10,484,403 oz. of gold recovered. Silicosis compensation cost therefore about 6d. per ton of ore milled and about 1s. 7d. per ounce of gold recovered. With an average of about 11,000 European workers employed underground, the cost was about 4s. per European underground shift. Net outstanding liability of the district's silicosis compensation fund on July 31, 1931, was £6,900,000.

In Ontario the total cost of silicosis compensation in 1932 was $301,067.75.[7] Gold mines of the province in that year milled[8] 5,497,177 tons of ore, recovering 2,264,051 oz. of gold. Assuming that the silicosis compensation is chargeable solely against the gold mining industry of the province, the cost per ton of ore milled was about 5½c., and the cost per ounce of gold recovered was about 13c.

At Broken Hill, Australia,[9] a total of £1,141,938 had been expended as of June 30, 1933, for compensation of mine workers suffering from pneumoconiosis or tuberculosis in the twelve and a half years since the enactment in 1920 of the Workmen's Compensation (Broken Hill) Act. During this period, Broken Hill mines hoisted about 13,000,000 tons of ore.[10] Compensation cost per ton of ore hoisted was therefore about 1s. 9d.

Conclusion

The study made of the trend of silicosis compensation seems to lead to the conclusion that the legal means that have been employed in other countries, particularly those for the compensation of mine workers, must inevitably be followed by the adoption of similar procedure in the United States. At the moment silicosis in this country has associated with it certain "racket" features that operate against the best interests of both employer and employee. Remedy for the situation would appear to rest in the formulation of some such plans as those to which reference has been made. Competent medical control is an essential feature of such plans, and avoidance of the aforesaid racket features would seem to be possible only through the exercise of such control. In this connection, the following excerpt from the recent report of the Committee on Pneumoconioses of the American Public Health Association (see footnote No. 4) is especially pertinent:

"In contradistinction to the practice in America, foreign laws for the compensation of silicosis and other dust diseases of the lungs provide for careful medical control. This feature is present in all the schemes and acts of the British Empire. Some of the continental European compensation laws, such as that of Germany, obtain such control because they are part of the whole social insurance system.

"Without some form of medical control, the management of compensation for a disease such as silicosis would be difficult. It is a disease in which the definition of disability is obscure. Medical advice is necessary to determine whether the worker's health is impaired to a degree which constitutes disability or whether his condition has reached a point where exposure to dust will jeopardize his future working capacity. Furthermore, medical control is advisable following the inclusion of the disease in the compensation law because gradual education is likely to bring about an increased number of claims. In the United States, until recently, claims have not been very numerous, since the disease was not specifically mentioned in the laws, and workmen may not have been aware that they might be entitled to compensation or may have feared that they would become involved in complicated disputes in court. However, in Great Britain there has been a steady increase in claims and in expense following the enactment of schemes for the compensation of silicosis. Later a decrease may set in. For instance, in South Africa it is thought that the number of new cases of simple silicosis is beginning to show a decline."

[5] "Report of the Miners' Phthisis Board for the Period 1st April, 1931, to 31st March, 1932." Department of Mines and Industries, Pretoria, South Africa.

[6] Forty-second and Forty-third Annual Reports of the Transvaal Chamber of Mines, 1931 and 1932, Johannesburg, South Africa.

[7] Report for 1932 of The Workmen's Compensation Board, Ontario; Toronto, Ont., Canada.

[8] Preliminary Report on the Mineral Production of Ontario in 1932. Bulletin No. 88, Department of Mines, Province of Ontario, 1933.

[9] From Annual Report of New South Wales Workmen's Compensation Commission, as published in the Nov. 1, 1933, issue of *The Barrier Miner*, Broken Hill, N.S.W., Australia.

[10] "Australian Mining Industry, 1908-1933," by Harold S. Elford, pp. 19-27, *Chemical Engineering and Mining Review* (Melbourne, Australia), Oct. 5, 1933.

Trends and Developments In the Industry

President Authorizes Purchase of Silver

Executive Order Ratifies International Agreement and Directs Government to Buy Annually at Least 24,421,410 Ounces of Newly Mined Metal Over Period of Four Years—Plan Fixes Settlement Price at 64½c.

GOVERNMENT purchase of newly mined silver at the rate of 64½c. an ounce was announced on Dec. 21. President Roosevelt, through an Executive Order signed on that day, ratified the international silver agreement, negotiated last July by Senator Key Pittman at the London Economic Conference, and provided for the purchase by the Treasury until Dec. 31, 1937, of domestic silver mined subsequent to that date, to the extent of at least 24,421,410 ounces annually, the amount prescribed by the agreement. Under the terms of the silver-purchase plan, the newly mined silver will be acquired by the government on the statutory basis of $1.29 an ounce, but 50 per cent of each lot of metal tendered to the Mint will be retained in the form of bullion by that agency as seigniorage and to cover service charges in connection with coining the other 50 per cent into silver dollars for the seller. The arrangement therefore results in the seller receiving 64½c. an ounce for his metal.

Regulations governing the purchase and coinage of silver under the terms of President Roosevelt's proclamation of Dec. 21 were made public by Acting Secretary Morgenthau of the Treasury on Dec. 30. In addition to the regulations, he transmitted to the mints a form affidavit to be made out by the person delivering the silver, with supporting affidavits by the miners.

In the instance of silver of wholly domestic origin, the affidavits will set forth that the silver to be received has actually been mined from natural deposits in the United States, or a place subject to its jurisdiction, subsequent to the date of the proclamation. When domestic silver is mixed with secondary or foreign silver, the coinage mints will receive that part of such mixture which the mints are satisfied is not in excess of the amount which has been mined subsequent to Dec. 21, 1933, from natural deposits in the United States or any place subject to its jurisdiction.

Persons who deliver silver to the mints for coinage are required to file monthly reports showing all silver mined or acquired subsequent to Dec. 21, 1933. Reports are to be itemized as to domestic, foreign, and secondary silver and are to show: (a) amount on hand at the beginning of the period covered by the report; (b) the amount received during the period and the sources from which received; (c) the amount smelted or refined during the period; (d) the amounts and consignees of all silver delivered during the period; (e) amount of silver remaining on hand at the end of the period.

The text of the President's statement, his proclamation, and the Treasury regulations follow:

President's Statement

"Under the clear authority granted to me by the last session of the Congress, I have today, by proclamation, proceeded to ratify the Treasury Department agreement with regard to silver, which has already been put into effect by the Government of India and which I understand other nations concerned are about to act on.

"This proclamation, in accordance with the Act of Congress, opens our mints to the coinage of standard silver dollars from silver hereafter produced in the United States or its possessions, subject to the depositors of such silver surrendering to the government one-half of it as seignorage and to cover all usual charges and expenses. The dollars coined from half of such newly mined silver will be returned to the depositor. The half surrendered to the government will be retained in the Treasury.

"It will be remembered that at the London Conference sixty-six governments unanimously adopted the silver resolution proposed by our government, providing in substance that these governments would refrain from the policy and practice of melting up and debasing silver coins, that they would replace low-valued paper money with silver coins, and that they would not enact legislation that would depreciate the value of silver in the world market.

"This resolution, however, was contingent upon an agreement between the governments of those countries producing large quantities of silver and the governments of those countries holding or using large quantities, looking to the elimination of an unnatural oversupply of silver on the markets of the world. This agreement, of course, was for the purpose of allowing demand and supply to govern the prices of silver by the limitation and neutralization of this oversupply derived from the melting up of silver coins.

"India had the power to dispose of, on the markets of the world, at any time, and at any price, hundreds of millions of ounces of silver. In fact, India had the power and capacity to dump silver derived from the melting up of Indian silver coins in an amount equal to the world's production from the mines for the period of two years. This power and the uncertainty attending its execution was destructive of the value and stability of silver throughout the world.

"China agreed, during the period of four years commencing Jan. 1, 1934, and ending Jan. 1, 1938, not to permit the sale of any silver derived from the debasing or melting up of silver coins. India agreed to limit the sales of such silver to a maximum of 35,000,000 ounces annually during such period, and Spain agreed not to sell in excess of

Silver Production Statistics

Silver production of the world during November amounted to 14,100,000 oz., against 15,012,000 oz. in October, according to the American Bureau of Metal Statistics. World's production of silver in 1932 was at the rate of about 14,000,000 oz. per month, contrasted with 13,430,000 oz. monthly in the first eleven months of the current year.

United States production during November was estimated at 1,863,000 oz., against 1,781,000 oz. in October, and 2,052,000 oz. in November, 1932.

During 1932 the United States produced 23,980,773 oz. of silver, according to the Bureau of the Mint. This compares with 30,932,050 oz. in 1931, 50,748,127 oz. in 1930, and 61,327,868 oz. in 1929.

5,000,000 ounces of such silver annually during such period. After such sales, these governments are to be bound by the general resolution adopted at the London Conference to which I have heretofore referred.

"As a condition of the agreement by China, India and Spain, however, it was required that Australia, Canada, Mexico, Peru and the United States should take silver from the production of their respective mines to the gross amount of 35,000,000 ounces annually for such period of four years. The United States, by reason of its large population and its large silver production, agreed to take from its mines annually at least 24,421,410 ounces of silver during such period.

"The production of the United States for 1932 was approximately 24,000,000 ounces of silver."

The Proclamation

Whereas, by Paragraph (2) of Section 43, Title III, of the Act of Congress, approved May 12, 1933 (Public No. 10), the President is authorized "by proclamation to fix the weight of the gold dollar in grains nine-tenths fine and also to fix the weight of the silver dollar in grains nine-tenths fine at a definite fixed ratio in relation to the gold dollar at such amounts as he finds necessary from his investigation to stabilize domestic prices or to protect the foreign commerce against the adverse effect of depreciated foreign currencies, and to provide for the unlimited coinage of such gold and silver at the ratio so fixed; and

Whereas, from investigations made by me, I find it necessary, in aid of the stabilization of domestic prices and in accordance with the policy and program authorized by Congress, which are now being administered, and to protect our foreign commerce against the adverse effect of depreciated foreign currencies, that the price of silver be enhanced and stabilized; and

Whereas, a resolution presented by the delegation of the United States of America was unanimously adopted at the World Economic and Monetary Conference in London on July 20, 1933, by the representatives of sixty-six governments, which in substance provided that said governments will abandon the policy and practice of melting up or debasing silver coins; that low-valued silver currency be replaced with silver coins and that no legislation should be enacted that will depreciate the value of silver; and

Whereas, a separate and supplemental agreement was entered into, at the instance of the representatives of the United States, between China, India and Spain, the holders and users of large quantities of silver, on the one hand, and Australia, Canada, Mexico, Peru and the United States on the other hand, as the chief producers of silver, wherein China agreed not to dispose of any silver derived from the melting up or debasement of silver coins, and India agreed not to dispose of over 35,000,000 ounces of silver per annum during a period of four years commencing Jan. 1, 1934, and Spain agreed not to dispose of over 5,000,000 ounces of silver annually during said period, and both of said governments agreed that at the end of said period of four years they would then subject themselves to the general resolution adopted at the London conference, and in consideration of such limitation it was agreed that the governments of the five producing countries would each absorb from the mines in their respective countries a certain amount of silver, the total amount to be absorbed by said producing countries being 35,000,000 ounces per annum during the four years commencing the first day of January, 1934; that such silver so absorbed would be retained in each of said respective countries for said period of four years, to be used for coinage purposes or as reserves for currency, or to otherwise be retained and kept off the world market during such period of time, it being understood that of the 35,000,000 ounces the United States was to absorb annually at least 24,421,410 ounces of the silver produced in the United States during such period of time.

Now, therefore, finding it proper to cooperate with other governments and necessary to assist in increasing and stabilizing domestic prices, to augment the purchasing power of peoples in silver-using countries, to protect our foreign commerce against the adverse effect of depreciated foreign currencies, and to carry out the understanding between the sixty-six governments that adopted the resolution hereinbefore referred to; by virtue of the power in me vested by the act of Congress above cited, the other legislation designated for national recovery, and by virtue of all other authority in me vested;

I, Franklin D. Roosevelt, President of the United States of America, do proclaim and direct that each United States coinage mint shall receive for coinage into standard silver dollars any silver which such mint, subject to regulations prescribed hereunder by the Secretary of the Treasury, is satisfied has been mined, subsequently to the date of this proclamation, from natural deposits in the United States or any place subject to the jurisdiction thereof. The Director of the Mint, with the voluntary consent of the owner, shall deduct and retain of such silver so received 50 per cent as seigniorage and for services performed by the Government of the United States relative to the coinage and delivery of silver dollars. The balance of such silver so received, that is, 50 per cent thereof, shall be coined into standard silver dollars and the same, or an equal number of other standard silver dollars, shall be delivered to the owner or depositor of such silver. The 50 per cent of such silver so deducted shall be retained as bullion by the Treasury and shall not be disposed of prior to the thirty-first day of December, 1937, except for coining into United States coins.

The Secretary of the Treasury is authorized to prescribe regulations to carry out the purposes of this proclamation. Such regulations shall contain provisions substantially similar to the provisions contained in the regulations made pursuant to the act of Congress, approved April 23, 1918 (40 Statutes at large, page 535), known as the Pittman Act, with such changes as he shall determine prescribing how silver mined, subsequently to the date of this proclamation from natural deposits in the United States or any place subject to the jurisdiction thereof, shall be identified.

This proclamation shall remain in force and effect until the thirty-first day of December, 1937, unless repealed or modified by act of Congress or by subsequent proclamation. The present ratio in weight and fineness of the silver dollar to the gold dollar shall, for the purposes of this proclamation, be maintained until changed by further order or proclamation.

Notice is hereby given that I reserve the right by virtue of the authority vested in me to revoke or modify this proclamation as the interest of the United States may seem to require.

In witness whereof I have hereunto set my hand and caused the seal of the United States to be affixed.

Done at the city of Washington this 21st day of December, in the year of our Lord nineteen hundred and thirty-three, and of the independence of the United States of America the one hundred and fifty-eighth.

FRANKLIN D. ROOSEVELT.

By the President:

William Phillips,

Acting Secretary of State.

Treasury Regulations

Article 1. Silver which will be received—The United States coinage mints, under the conditions hereinafter specified and subject to the appropriate regulations governing the mints, will receive silver which any such mint is satisfied has been mined subsequent to Dec. 21, 1933, from natural deposits in the United States or any place subject to the jurisdiction thereof.

Such mints will also receive silver which forms a part of a mixture of domestic, secondary, and foreign silver provided such mints are satisfied that the aggregate amount of such mixture so received does not exceed the amount thereof which has been mined subsequent to Dec. 21, 1933, from natural deposits in the United States or any place subject to the jurisdiction thereof.

Article 2. Affidavits—Any individual, partnership, association, or corporation, hereinafter referred to as "person," delivering silver under the provisions of the Proclamation of Dec. 21, 1933, shall accompany each such delivery with a properly executed affidavit on form TS-1, and supporting affidavit or affidavits of the miner or miners on form TS-2, containing the information called for in such forms and executed under oath before an officer duly authorized to administer oaths.

Article 3. Evidence which may be demanded—Persons delivering silver under the provisions of these regulations shall furnish such further evidence as may from time to time be requested by the superintendent of any mint, including affidavits and sworn abstracts from books of account of any mines or any or all smelters or refineries, handling such silver.

Article 4. Settlement for Silver Delivered—The director of the mint, pursuant to the voluntary consent of the depositor, as required in the form of agreement to be executed in connection with affidavit TS-1, shall retain of such silver so delivered 50 per cent as seigniorage and for services performed by the government of the United States, and the balance of such silver so received—that is, 50 per cent thereof—shall be coined into standard silver dollars and the same, or an equal number of other standard silver dollars, shall be delivered to the owner or depositor of such silver. Any fractional part of one dollar due hereunder shall be returned in any legal tender coin of the United States.

Article 5. Records and Reports—Every person delivering silver under these regulations shall keep accurate records of all silver mined or acquired subsequent to Dec. 21, 1933, and such records shall be available for examination by a representative of the Director of the mint for at least one year after the last delivery.

Such person shall file with the director of the mint on or before the twenty-fifth day of each month after the date the first delivery is made a report covering the period of the preceding calendar month, provided that the first report shall cover the period from Dec. 21, 1933, to the end of the calendar month preceding the date of the report.

Such report shall be executed under oath before an officer duly authorized to administer oaths and shall be made on form TS-3 and shall contain all of the information called for in such form.

Every person delivering silver which has been mixed with secondary or foreign silver or both at a smelter or refinery, other than that of the person making the delivery, shall also file with each delivery of such silver an agreement properly executed under oath by a duly authorized officer of such other smelter or refinery that records will be kept and reports will be filed as provided in this article, and that such records will be available for examination by a representative of the director of the mint for at least one year after the last delivery.

Article 6. Forms—Any form, the use of which is prescribed in these regulations, may be obtained at any United States mint or assay office or at the Treasury Department, Washington.

Article 7. Revocation or Modification—The provisions of these regulations may be revoked or modified at any time.

H. MORGENTHAU, Jr.,
Acting Secretary of the Treasury.

Approved:
Franklin D. Roosevelt,
The White House, Dec. 30, 1933.

Increased Price for Newly Mined Silver Accelerates Mining Activity

PRESIDENT ROOSEVELT'S proclamation of Dec. 21 establishing a price of 64½c. an ounce for newly mined silver gave additional impetus to the increase in mining activity of recent months that followed the earlier governmental action providing for higher prices for newly mined gold. Throughout Nevada, according to reports, the advance in the value of silver was acclaimed with joy, expectations being that it would bring prosperity to many mining districts of the state. In Utah, mine operators hailed the President's proclamation as the best Christmas present the West has had in many years; re-employment of additional workers and expansion of operations were announced by several companies. A summary follows of the principal developments in the various mining districts during the past month.

Nevada

Opening of the mints to silver at a stabilized price of 64½c. was acclaimed with joy throughout Nevada, and the general opinion prevailed that it will stimulate mining and bring a medium of prosperity to many districts. The Belmont and Montana mines at Tonopah, for instance, are preparing to resume operations, the former under the leasing system. Tonopah Extension may expend $500,000 to make accessible large deposits of high-grade ore developed on deep levels, mining of which was suspended two years ago. Treadwell-Yukon is expected to resume operation of mines and concentrator at Tybo, producing silver-lead and silver-zinc ore.

Shipments of gold ore are being made from the Lime Point district, near Beowawe, where Cuba Consolidated Mining is operating the Gold Quartz property. Operations are also being carried on at the Beowawe Gold mine by Lee Lakin, and in the McCracken property.

Production at the Bristol Silver Mines, near Pioche, Nev., was materially stimulated recently by the opening of higher-grade ore on the 1,200 level. At the Combined Metals mine, at Pioche, operated by the Snyder and National Lead interests, 100 men are employed. Another Pioche mine, the Prince Consolidated, is planning to resume operations soon.

Immediate construction of a mill by East Standard Mining at the Sleeping Beauty mine, at Midas, Nev., leased to the company for three years, was announced by Harry S. Joseph, consulting engineer to the East Standard and Miners Gold companies. A 40-ton Lane mill is at the mine, and a 9x12-in. crusher and a 60-hp. diesel engine are in transit from Salt Lake City. An adequate water supply has been assured by a 50-ft. tunnel completed recently. The Sleeping Beauty mine is operated by East Standard and subleasers, with P. Devine in charge of operations.

The shaft of Mountain City Copper, near Mountain City, in Elko County, has reached a depth of 380 ft. Striking of a small flow of water caused the management to speed advancement of the 400 level from the old shaft to a point under the new three-compartment shaft, so that the shaft may be drained before sinking any deeper. From 10 to 15 ft. of progress daily has been made in advancing the drift. The new 30-mile transmission line, built from Jarbridge, is operating satisfactorily and conveying 4,000-volt current to operate the new electric hoist, compressor, and other equipment installed recently. At present 60 men are employed. When the surface plant is completed, the operation force will consist of 45 men.

Miners Gold, a corporation financed by Silver Shield Mining, of Salt Lake City, Utah, has opened a vein of gold-silver ore at Gold Circle, in a prospect adjoining the Elko Prince mine. Development is through an adit 900 ft. long, which has been advanced 300 ft. in a vein averaging three and a half feet, with 350 ft. of backs.

Gold Circle Consolidated is driving to reach the vein on the 300-ft. level of the Elko Prince.

Jameson & Graven, leasing on the 800-ft. level of the Tonopah Divide mine, found a gold vein back of the Brougher silver vein that produced 104 tons of high-grade ore.

Utah

Establishment of a market for silver at 64½c. an ounce by President Roosevelt was hailed by Utah mining men as being the best Christmas present the West had had in many years. Believing that this action was but the forerunner of better things for the entire industry, prospectors and operators look forward to a prosperous year.

Continued on page 41

Sacked gold-silver ore ready to be shipped from a reopened Nevada property to a Salt Lake Valley smelter. Higher prices for the precious metals have stimulated activity at many small scale operations such as this—the mine of Caliente Cobalt Mining, near Caliente, Nev.

Hearings on Proposed Zinc and Lead Codes Elicit Relatively Few Objections

PUBLIC hearings on the proposed zinc and lead codes were held in Washington on Dec. 8 and 22, respectively, under Deputy Administrator Walter A. Janssen. Several objections were made to the labor and marketing provisions of the zinc code, which was presented by the American Zinc Institute, representing about 98 per cent of the volume of the industry. A request for clarification of the trade-practice rules for metallic foil products, besides some opposition to general labor provisions, was expressed at the lead code hearing, which code was presented by the Lead Industries Association, representing more than 90 per cent of the industries. A summarized record of the two hearings follows.

Zinc—Though several objections were made to the labor and marketing provisions of the proposed zinc code, the public hearing held under Deputy Administrator W. A. Janssen in Washington on Dec. 8 disclosed that virtually complete accord exists among producers who comprise the nine divisions of the industry. The hearing was indefinitely recessed after R. M. Roosevelt, president of the American Zinc Institute, who presented the code in behalf of the industry, announced that he would submit to the Administration a brief dealing with the various suggestions proposed by those who spoke at the gathering.

The nine divisions in the proposed code are: Mining (five geographical districts); Prime Western Smelting; High Grade Zinc; Secondary Zinc; Rolled Zinc; Zinc Alloy; Zinc Oxide; Lithopone; Sulphuric Acid.

Minimum wages in the code as submitted range from 30c. per hour in the Southern Mississippi Valley and Southwestern districts of the mining division to 39c. in the High Grade division, with clerical and sales employees to receive not less than $14 per week. A maximum work week of 40 hours was specified for the latter, with other workers to have a schedule of not more than 42 hours per week averaged over successive thirteen-week periods.

Waldo C. Holden, representing the American Federation of Labor, voiced objections to the wage rates, pointing out that hazards of the industry made for an extremely short span of life among underground and smelter workers and proposed a minimum wage of 50c. per hour for all such workers, with a maximum week of 35 or 36 hours.

Roy Brady, Dr. J. S. Gould, and Dr. Edwin C. Eckel, all representing the NRA Labor Advisory Board, objected to the labor provisions. Pleas for better working conditions and higher wages were made by Jesse Gonzalez and C. M. Marino, members of Mine, Mill and Smelter Workers Union No. 95, of Langeloth, Pa.

W. L. Chandler, representing the NRA Consumers' Advisory Board, voiced objection to the code's proposal for filing prices as well as to the provision for assigning production quotas. He also objected to the prohibition against consignment selling and "sliding scales" for quantity purchases, stating that these were highly desirable from the consumer's standpoint when equitably controlled. Mr. Chandler asked that consumers be given representation on the Code Authority, and that no modifications or additions be made to the code until after public hearing on such proposals.

Walter A. Janssen

Before assuming his duties as a deputy administrator under the NRA, Mr. Janssen was professionally engaged as a consulting chemical and metallurgical engineer. He has also been associated in an executive capacity with a number of leading industrial companies. From 1930 to 1932 he was general manager, Vanadium Alloys Corporation; prior to that, general manager of the steel foundry division, Pittsburgh Malleable Iron Company; assistant vice-president, American Steel Foundries. Following his graduation from the University of Wisconsin in 1907, Mr. Janssen joined the staff of Bettendorf Manufacturing Company, holding the position of general superintendent of the company in 1917, when he accepted the position of operating manager of Canadian Steel Foundries, Ltd.

O. M. Kile, representing the Mail Order Association of America, characterized the code as one of the most drastic in its price-control features that ever had come to his attention.

R. G. Nicholson, of Kusa Spelter Company, urged establishment in the code of a ratio between the price of slab zinc and zinc ore.

Lead—The public hearing on the code for the lead industries, held in Washington on Dec. 22, brought out some opposition to the general labor provisions and a request for clarification of the trade-practice rules for metallic foil products. With those exceptions, the measure met with full approval of all present. Deputy Administrator W. A. Janssen presided at this hearing also.

Clinton H. Crane, president of the Lead Industries Association, presented the code, Felix E. Wormser, secretary of the association, read the code article by article, and the opposition was given an opportunity to state objections and file briefs before Dec. 29 on the questions raised.

The code in the form presented differed from the original document in that it is more explicit on the labor provisions, recognizing reasonable standards for safety and health and existing state laws that may impose more stringent requirements than those imposed by the code. General trade-practice provisions are included covering price lists for lead pigments and bases for sales, as well as rules of fair practice for metallic lead products and foil. No attempt has been made to regulate prices for pig lead.

The term "industry" in the code includes the mining of lead ore and/or the concentrating thereof, the smelting of lead ore or concentrate and lead-bearing scrap or drosses, the manufacturing of pig lead, antimonial pig lead, lead pigments, metallic antimony, metallic lead products, allied products defined as "metallic lead products," and "metallic foil products."

The labor provisions call for a 40-hour work week averaged over a period of thirteen weeks, for all production workers in the industry, and 40 hours during a one-month period for office and clerical workers. The hourly wage rate is set at 35c. for production workers, unless the rate was less than 35c. for the same class of work on July 15, 1929, in which case it was not to be less than the hourly rate paid on that date, and in no event less than 30c. except for cleaners and watchmen.

W. C. Holden, representing the American Federation of Labor, objected to the wages and hours provisions and indicated that he would file a brief on the changes desired.

Thomas H. Brown, of the International Union of Mine, Mill and Smelter Workers, declared that the maximum hours established in the proposed code meant little to the mining employees in the industry. He pointed out that consideration has not been given to the question of time lost to the worker in traveling between the point of operation and the top of the shaft. He recommended a five-day week and six-hour day.

Dr. J. S. Gould, of the NRA Labor Advisory Board, objected to the hours of labor and wage rates. He questioned the wording of Section 4 of Article 5, which states that every employer shall make reasonable provision for the safety and health of his employees and asked that the term "reasonable" be defined. Dr. Gould suggested that the safety rules of the United States Bureau of Mines be incorporated in the proposed code.

W. H. Edmunds, acting for the Consumers' Advisory Board, requested that one member of the code authority be appointed who will be charged with protecting the interests of consumers. He called for interpretation of the section relating to the trade-practice rules for pigments, with special emphasis on the reasons why uniform bases for sale

should be considered beneficial to certain sections of the industry and not to others.

L. Muscat, of the Standard Rolling Mills, Brooklyn, N. Y., offered several clarifying amendments to the trade-practice sections for metallic lead products and metallic foil products. Tinfoil mixtures, he said, are not always uniform, and a strict interpretation of the rules contained in the code might cause unnecesary hardship on this division of the industry.

The hearing recessed at 11:30 a.m., after a session of little more than one hour. Deputy Administrator Janssen announced that the hearing was recessed subject to the call of the administrator on 48 hours' notice.

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Ventures Limited Treating Mill Product in Small Smelter

Ventures Limited, which owns the Opemiska copper-gold property, 225 miles northeast of Rouyn, Que., Canada, and 150 miles from the railway, having proved at Falconbridge Nickel that a deposit of moderate grade can be treated successfully in a small blast furnace, has undertaken similarly to treat the product of a 300-ton mill at Opemiska in a small copper smelter, whose location has not yet been announced. The larger part of the 150 miles from the railway is served by a water route, and surveys are now being made with a view to building a narrow-gage railway for the remaining distance. The concentrate from the Beattie gold mine, also controlled by Ventures, will be treated at this new smelter.

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Quicksilver Tariff Hearing Scheduled for Jan. 15

The U. S. Tariff Commission will conduct a public hearing at the office of the Commission in Washington, D. C., at 10 a.m. on Jan. 15 on the question as to whether quicksilver is being imported into the United States in substantial quantities or increasing ratio to domestic production and on such terms or under such conditions as to render ineffective or seriously to endanger the maintenance of the President's Re-employment Agreement and/or the code of fair competition proposed to be entered into under the National Industrial Recovery Act.

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British Interests Negotiating For the Boliden Mine

British interests, according to persistent rumors, have expressed a willingness to negotiate for the purchase of a half interest or all of the Boliden Gold mine, which was one of the assets of Kreuger and Toll. The mine is mortgaged to the Swedish banks. Their consent and that of the Swedish Government and the Boliden company would have to be obtained before a sale could be effected.

Mining Congress Discusses Vital Questions

At its annual convention in Washington, D. C., Dec. 13-16, 1933, the American Mining Congress gave special consideration to silver, federal taxation, the 30-hour week, the National Securities Act, and the Bureau of Mines.

Senator Pittman spoke hopefully of the future of silver as a monetary metal and predicted the rise of both the domestic and world price. Opposition was voiced to some of the taxation proposals being considered by the Ways and Means Committee of the House, particularly the proposed arbitrary reduction of 25 per cent in depreciation and depletion allowances. Anticipating strong agitation for a uniform 30-hour week for all industry, resolutions were passed opposing blanket regulation of hours by hasty and ill-considered legislation. Another resolution called upon Congress to consider amendments to the National Securities Act to facilitate the financing of legitimate projects without weakening the approved purposes of the Act in the protection of investors.

Howard I. Young,

New president of the American Mining Congress

A committee previously appointed to canvass the mineral industries regarding activities of the Bureau of Mines reported specific recommendations for more field work, concentration of experiment station work at four stations (one each for metals, coal, oil, and nonmetals), extension of safety work, continuation of statistical activities, and research work. Director Scott Turner discussed the present plight of the Bureau, after which a committee was appointed to voice the protest of the mineral industries against its further disintegration.

Officers elected for 1934 were: President, Howard I. Young, president, American Zinc, Lead & Smelting Company; first vice-president, A. E. Bendelari, president, Eagle-Picher Lead Company; second vice-president, D. D. Moffatt, vice-president, Utah Copper Company; third vice-president, J. B. Putnam, Pickands Mather Company; secretary, J. F. Callbreath. Messrs. Young, Putnam, and W. J. Jenkins comprise the executive committee. New directors, elected for three years, are: Charles H. Segerstrom, president Carson Hill Gold Mining Company, and A. B. Jessup, vice-president Jeddo Highland Coal Company.

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Increased Silver Price Accelerates Mining

Continued from page 39

Increased activity was predicted by George W. Snyder, of W. F. Snyder & Sons, who announced that Nevada, Utah, and Idaho properties of the Snyder interests would at once increase production and add 400 men to their payrolls. An immediate resumption of activity at the Park City Consolidated property, at Park City, was announced by manager J. J. Beeson, who said that a crew of 30 men would be put to work and that this number would soon be increased to 50. Officials in charge of operations at the older mines—Silver King Coalition, Tintic Standard, Park Utah, and the Bingham properties—although encouraged by the turn in events, announced that they were waiting to analyze the President's proclamation before increasing production.

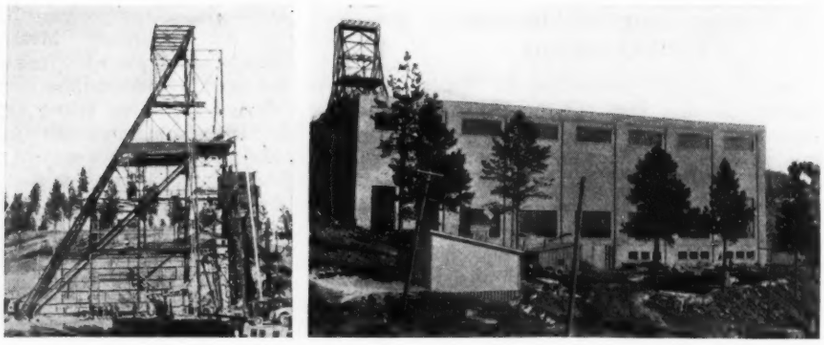
Meanwhile, the high price of gold has stimulated the search for and production of gold ores. Announcement was made that Chief Consolidated Mining would resume shipments of low-grade gold ore from the Eureka Lilly property, in the Tintic district; south of Delta, Utah, in the New Klondyke district, a force of men was put to work sluicing gravel on a gold prospect.

Laying of 5 miles of 3-in. pipe to augment the water supply for the Manning Gold Mines' mill, near Mercur, is being completed. With the new pipe line completed, the company will lift about 20 gal. of water per minute from the springs at Fairview 1,000 ft. to the mill, thereby increasing the capacity of the mill to 400 tons daily, as compared with an average of 265 tons for December. Under the direction of Superintendent W. J. Franklin, the company is installing two more 45-ft. Dorr thickeners and two more Deveraux 16x20-ft. agitators. A 15-hp. high-pressure Triplex pump, with a 2x6-in. stroke, will be used for pumping the water.

California

Gold Exploration, a subsidiary of Tintic Standard Mining, of Utah, has completed installation of surface equipment on the Blue Point placers at Smartsville, and is engaged in sinking a shaft to bedrock.

According to a report from Grass Valley, Empress Mining, operating the Empress mine, about 4 miles northwest of Grass Valley, has completed plans for immediate erection of a 200-ton mill.



New headframe and hoist house at the Ross shaft of the Homestake Mining Company, Lead, S. D. Height of the headframe is 125 ft. from the ground to the center line of sheaves, and over-all dimensions of the hoist house are 200x80x60 ft.

The reduction plant is treating daily about 80 tons of ore, obtained from various levels.

After years of inactivity, the old Zeibright mine, near Emigrant Gap, controlled by Empire-Star interests, is again producing. The property has a ten-stamp mill and other equipment.

About 100 tons of sulphur a day are being mined from the Leviathan mine, near Markleeville, Alpine County; the refined product is shipped to San Francisco. The property is operated by Leviathan Sulphur, a John Hays Hammond interest. About 50 men are employed.

Lava Cap Mining, operating the Lava Cap properties near Nevada City, has completed surface structures and the 200-ton mill at the Central shaft. Milling operations are to start soon.

About 900 acres have been added to the holdings of the Calaveras Central Mining by the acquisition of the Calmo property near San Andreas. Early rehabilitation of the mine is planned.

Milling operations have been resumed at the Beebe mine, at Georgetown, following the installation of two cradle-mounted Hardinge-Hadsel mills of new design. Each mill has a capacity of about 200 tons a day.

Central Eureka Mining has started work deepening the old Eureka shaft at Sutter Creek an additional 200 ft., to explore the ground below the 2,300-ft. level. The company recently added 30 men to its payroll, bringing the total of men employed to 140.

Rehabilitation work is progressing satisfactorily at the old Keystone mine, Amador City, with a crew of ten men engaged in reconstructing surface buildings and equipment. The management plans to extend the shaft an additional 1,000 ft.

Work is being pushed at the Eagle Bird gold mine, at Washington, by Bagdad Copper, new owner of the old producer. Installation of mining machinery and a new headframe has been completed, and sinking of the shaft to 500 ft. is progressing satisfactorily. J. W. Still is in charge of operations.

According to a report from Nevada City, Sixteen to One Extension Mines, operating in the Alleghany mining district, plans to sink a 1,000-ft. shaft to intersect the Sixteen to One vein system. The property adjoins the Tightener group of claims operated by Sixteen to One Mining.

Arizona

In Yavapai and Mohave Counties, Arizona's principal gold-producing counties, the number of small gold properties in operation continues to increase. Among the milling plants in Yavapai County which have started treating ore, or which are about to start, are the following: Davis-Dunkirk, 100-ton flotation plant, shipping concentrate to El Paso; Oro Grande, 50-ton flotation plant, about ready for operation; Golden Eagle, 25-ton plant, operating; Black Diamond, small stamp mill, operating; Webber and Webber, small stamp mill, operating; Midnight Test, 250-ton flotation plant, about ready for operation; Money Metals, pilot plant under construction; Lealand Dividend, 50-ton flotation plant, shipping to El Paso; Union Jessie, 50-ton flotation plant, shipping to El Paso; Crown King, 50-ton flotation plant, operating; Gold Belt, 75-ton flotation plant, shipping to El Paso.

The old stamp mill at the Kendall Tunnel property near Prescott is being remodeled by Trinity Gold Mining, and Fahrenwald flotation cells are being added. American Smelting & Refining is conducting a diamond-drilling test of the Octave mine, at Octave, north of Wickenburg.

In Mohave County, Pioneer Gold Mining has a crew of eighteen men on development work on the 150, 230, and 350 levels of the Pilgrim mine at Chloride. The Boriana tungsten mine, at Yucca, has increased its operating personnel to 35 men. A small mill is being installed at the New Moon property, in Mineral Park, where values are principally in silver and lead. Maurice Lauzon is operating a small mill on two shifts for Empire Mining at the Mossback, near Kingman. At Oatman, the Tom Reed mill is being overhauled. The S. & B. company, operating the Big Jim, at Oatman, and the Oro Grande, at Prescott, expects to extend its operations to include the Tintic, at Chloride.

The Gold Belt mine, in the Black Canyon district of Yavapai County, is producing 75 tons of ore per day and is treating that amount in its mill. Ed Shaw and associates, of Kingman, are operating a 900-yd. capacity plant on the King Tut placers, which consist of 4,000 acres of placer ground 35 miles east of Boulder dam and 50 miles north of Kingman.

Montana

To expedite the output of zinc ores, Anaconda Copper has a crew of men working on the upper levels of its Mountain Con and Green Mountain mines, in Butte, cleaning up preparatory to actual production. Zinc ores have not been mined from these properties for a long time. They are situated in the heart of the copper properties on "Butte Hill." No announcement has been made as to the amount of ore to be produced, but it will not affect present capacity production at the Orphan Girl mine of the company or that at the Emma mine of its subsidiary, Butte Copper & Zinc. The latter company, according to reports, recently struck some high-grade zinc ore more than 7 ft. wide on an intermediate level, known as the 1,500-ft. level.

Quite a little activity exists in the gold properties in and close to the old gold camp of Bannack, Beaverhead County. The largest property is the Bannack, controlled by Thompson Gold Milling and employing about 50 men in the mine and fine-grinding cyanide plant. The Hendricks property is working with a crew of ten men. Ermont is working under the direction of William Corbitt, and the Badger, next to the Ermont, is mining and shipping under the supervision of Hurly Leach. Among the other properties working in the district are the Senator, Gold Bug, Ingersoll, Anniversity, Crazy Jones, and the Curns.

Arthur V. Corry, Francis T. Morris, and associates have organized the Corry

World Production of Gold

(*American Bureau of Metal Statistics*)

In Fine Ounces

1933	September	October	November
United States (*a*)	271,000	252,000	256,000
Canada	236,000	243,000	248,000
Mexico	40,000	73,000	(*f*) 60,000
Colombia	27,000	(*f*) 30,000	(*f*) 30,000
Other South America	44,000	45,000	46,000
British India (*e*)	28,000	27,000	27,000
Japan (*e*)	41,000	35,000	(*f*) 38,000
Queensland	9,000	8,000	(*f*) 9,000
Western Australia	59,000	55,000	58,000
Other Australasia (*b*)	36,000	37,000	37,000
South Africa	902,000	909,000	898,000
Belgian Congo	21,000	20,000	19,000
Rhodesia	57,000	55,000	55,000
British West Africa	28,000	28,000	28,000
Russia (*c*)	(*f*) 160,000	(*f*) 160,000	(*f*) 160,000
Elsewhere (*d*)	(*f*) 85,000	(*f*) 90,000	(*f*) 95,000
Totals	2,044,000	2,067,000	2,064,000

(*a*) Includes Philippines. (*b*) Includes New Zealand and New Guinea. (*c*) Chiefly Siberia; 1933 estimated at average rate of 1932. (*d*) Includes West Indies, Central America, Europe, and Asiatic and African lands not separately reported: estimated. (•) Principal mines; nearly complete. (*f*) Conjectural.

Gold Mining Company, to work a gold property in the vicinity of Maxville, north of Phillipsburg, Granite County. Paul A. Gow, president of North Butte Mining, is also one of the officials.

South Carolina

At the Pioneer mine, near McCormick, S. C., a high recovery is being made from completely oxidized gold ore by flotation treatment of the ore in six 20-in. Sub. A cells, which were recently placed in operation. Reagents employed, per ton of ore treated, consist of 0.1 lb. of amyl xanthate, 0.05 lb. of Yarmor No. 2 pine oil, and 0.05 lb. of creosote. Spokane and New York interests are reopening the old Dorn mine, situated in the same district.

British Columbia's Mineral Output Increases During 1933

ACCORDING to an estimate presented by J. D. Galloway, Provincial Mineralogist, at the annual western meeting of the Canadian Institute of Mining and Metallurgy, held recently in Vancouver, mineral output of the province in 1933 will show some increase in value as compared with the record for 1932. The value of the 1933 output will probably be between $29,000,000 and $30,000,000, whereas the tonnage of ore treated will be about 4,000,000 tons, or slightly below that of last year. Average value of the ore treated will be somewhat higher as a consequence of the curtailment of production by some of the large low-grade mines, and owing to increased output from the smaller mines producing richer ore on the average. Gold production is valued at 4¼ million dollars, compared with 3¾ million dollars in 1932, based on the statutory price of gold. Actually, the return to the producer has averaged about $25 an ounce in Canadian funds, and on this basis the value of the output is approximately 6½ million dollars. The maximum output of gold in British Columbia in any one year was in 1913, when the value of the output was slightly in excess of six million dollars. During the year that has just ended, about 150 new gold-mining companies were incorporated in the province. Prospecting for gold has also been extremely active, as indicated by the fact that about 18,000 free miners' certificates were issued.

At the property of Cariboo Gold Quartz, near Barkerville, the objective of intersecting at depth the promising Sanders veins exposed at the surface, by the projection of a long tunnel which was started some three years ago, was achieved recently. A vein, the first of the group, was encountered about 2,200 ft. from the tunnel portal and at a depth of about 600 ft. below the surface. It is said to be from three to four feet wide, and to contain a substantial amount of gold.

Under the aegis of F. M. Wells, managing director of Cariboo Gold Quartz, another company, known as Cariboo Amalgamated Gold Mines, was recently incorporated to acquire properties in the Cariboo district located by him. The latest acquisitions by this company were the Liberty and Freegold claims on Proserpine Mountain within a mile of Barkerville, on which rich ore is reported to occur on small veins exposed at the surface. Last month the Premier company relinquished all its options in the Cariboo district.

Control of the Relief-Arlington Mines, near Erie, has been acquired by the W. N. O'Neill Company, of Vancouver, which since last June has been operating the properties under option. Attention was directed mainly to development of the Second Relief mine, in connection with which a surface tramway was constructed and additions were made to the mill. The latter has a capacity of 20 tons per day, but this is to be increased to 40 tons. Last summer about 600 ft. of drifting on the Second Relief vein on No. 5 level was done, much of it in ore of minable width and carrying satisfactory gold values. A crosscut is to be driven from the 5th level, to prospect four parallel veins. At the Kootenay Belle, in this camp, the capacity of the power plant has been trebled to expedite development. Directors of the Bralorne property are considering the subdivision of a company's holdings in the Bridge River district, and the organization of independently financed subsidiaries to undertake the development of sections of promise. The property consists of 58 claims extending 16,000 ft. along the mineralized belt on Cadwallader Creek. Developments heretofore have been confined, with remarkable success, to the old Lorne mine within the northwesterly section of the holdings. The present proposal is to alienate the southeasterly section, which will be divided into two groups of properties, one to include the Coronation claim, which, in view of its being adjacent to the Pioneer, possesses most attractive possibilities. The object of the plan is to expedite the development of the Bralorne area. Arrangements have been made for the merging of the Pioneer Extension, Plutus, and Dan Tucker properties in this area.

Development by Nicola Mines and Metals Limited of the Donohoe and Planet groups of claims on Stump Lake, in the Nicola district, is proceeding satisfactorily. Exploration at present is confined to three major parallel veins known as the Enterprise, Tubal Cain, and Joshua. An adit is being extended from the Enterprise workings to intersect the Tubal Cain vein; eventually it will connect with the Joshua workings and be used as the main haulageway to the mill. Since crossing the Tubal Cain vein through a sheer zone, the tunnel has cut several well-mineralized stringer veins and is expected to intersect the Joshua vein by the end of this month. The Joshua shaft is being sunk to the 1,000-ft. level, and, by the time the tunnel intersects this vein, should be below the 550-ft. level, at which point a station will be cut and a drift extended the full length of the vein, a distance of more than 3,000 ft. Driving of a drift, 1,000 ft. north and 2,000 ft. south on the Tubal Cain vein from the point of intersection with the crosscut tunnel, is also planned.

In the Boundary district, the old Jewel gold mine has been acquired and is being operated with encouraging results by the Dentonia company, of Calgary. In raise workings, a 4-ft. high-grade vein was recently discovered. A body of good milling ore 9-ft. wide has also been opened up in tunnel workings.

Shipment of high-grade silver ore from the Sally mine has been resumed and an initial shipment was made last month from the Beaver Silver property. At the Union, in Franklin camp, owned by the Hecla Mining Company, a cyanide plant is being installed to treat the accumulated tailing.

The first shipment of ore was made recently from the California, in the Nelson area, which was recently reopened. Development at the old Athabasca-Juno-Venus Gold Mines, which were acquired in February last by the Noble Five Company, has proved satisfactory. On the Juno vein, on the second level, drifting exposed ore over a length of 270 ft., having an average width of 2 ft. and containing substantial amounts of gold. On the Athabasca, a tunnel has been stated that will give a depth on the known oreshoots of 300 ft. and additional length on the strike of the vein of 500 ft.

The Euphrates property was recently reopened, and trenching on what is known as the Lost Cabin vein has indicated high gold values over substantial widths. The Tamarac property in the Ymir camp was acquired recently by New York interests.

In the Portland Canal district production is being maintained by the Premier and, on a smaller scale, by the Dunwell, Ben Ali, Bayview, United Empire, and Spider properties. Development work has been resumed on the Big Missouri and is also in progress on the Unicorn, Salmon Gold, and Georgia River properties.

Arrangements are being made for the resumption of operations on the Dunwell mine by the company. The property has been leased during the past year.

Personal Notes·Comment·Criticism

Donald Gill has left London for Western Australia. He expects to be absent from England for about six months.

Harry E. Sparks has been appointed manager of the Cadillac O'Brien gold mine, in northwestern Quebec.

Harold A. Titcomb will soon return from London to his home in Farmington, Me.

H. A. Tobelmann has returned to Salt Lake City after two years' visit to Africa.

F. R. Weekes is spending the winter in California. His address is Pine Inn, Carmel.

Paul W. Avery, metallurgical engineer for Amparo Mining, at Etzatlan, Jal., Mexico, is spending the holidays at his home in Palo Alto.

P. R. Bradley, president of Alaska Juneau, has returned to San Francisco from a tour of inspection to Juneau, Alaska.

Jay A. Carpenter, professor of mining, Mackay School of Mines, University of Nevada, recently visited San Francisco on professional business.

Horace G. Young has returned to Toronto after examination of mining properties in the Kenora district of western Ontario.

Stuart French, who for years was general manager of the Copper Queen mines at Bisbee, was a recent visitor in Phoenix from his home in Pasadena.

C. N. Gerry and **Paul Luff,** from the Salt Lake office of the United States Bureau of Mines, are visiting Arizona mining districts.

Wilbur H. Grant, consulting mining and geological engineer of San Francisco, has gone to Libby, Mont., on professional business.

Ralph J. Orynski, mill superintendent, Mexican Candelaria Company, Contra Estaca, Sin., Mexico, is vacationing in San Francisco.

William Koerner, of Superior, was elected governor of the Arizona chapter of the American Mining Congress at the recent election in Phoenix. He succeeds **Michael Curley,** of Ajo.

Charles F. Ayer, president of Magma Copper, recently visited Arizona to attend a meeting of the board of directors of the Boyce Thompson Southwest Arboretum at Superior.

Prof. Albert H. Fay, of the department of mining engineering, Lafayette College, Easton, Pa., was elected chairman of the Lehigh Valley Section of the A.I.M.E. on Dec. 5.

R. J. Lemmon, metallurgical engineer for Imperial Chemical Industries, Ltd., London, has returned from an extensive

tour of South American mining properties.

Walter L. Pennick, manager of Hardinge-Western Company, has returned to San Francisco after an extensive trip through the mining districts of the Pacific Northwest.

Walter D. Abel completed his mine-examination work in the Searchlight district of Nevada early in November and has just returned to Los Angeles from a month's trip to the State of Chihuahua, Mexico.

W. F. Allen, Jr., who for the past six years has been general manager of the Yellow Aster Mining & Milling Company at Randsburg, Calif., may be reached at 651 West 34th St., Los Angeles.

F. M. Connell is visiting the Veraguas mine, in Panama, where a new mill has just been put in operation. Mr. Connell represents the Toronto interests that have financed the reopening of this gold property.

Philip D. Wilson, for many years with American Metal, has returned from a professional trip to California and Mexico, to become associated as mining engineer with Pardners Mines Corporation, 230 Park Ave., New York.

Hon. Michael Dwyer, Minister of Public Works and Mines in the recently elected Liberal government of Nova Scotia, is the first mining man to hold that important portfolio in the provincial government.

Dr. Colin G. Fink was presented with the Perkin Medal of the Society of Chemical Industry on Jan. 5. Dr. Fink is the author of a paper on Scientific Research presented in this issue of *E.&M.J.*

J. M. Forbes, who recently resigned as general manager of Siscoe Gold Mines, left Montreal early in November for East Africa, where he will represent the interests of Hollinger Consolidated in the Kakamega gold field.

Merle H. Guise is prospecting for dredging ground in the Circle City district north of Fairbanks, Alaska. He went through from the coast to the interior by plane, which is now being generally used by mining men in the North.

John E. Penberthy, who has been with Katanga, in Africa, for the past six years, left the Belgian Congo for the United States on Jan. 1. He was connected with Phelps Dodge for a number of years and at one time was assistant general manager at Nacozari, Sonora, Mexico.

L. E. Ives, for the last thirteen years sales manager and shipping agent at Cleveland, Ohio, for Clement K. Quinn & Company, miners and shippers of Lake Superior iron ores, and before 1920 business manager of *Engineering and Mining Journal,* has opened his own ore and Lake transportation office at 1311 Guarantee Title Building, Cleveland.

James J. Denny, of Schumacher, Ontario, metallurgist, mining engineer, and graduate of Queen's University, has been awarded a medal of pure platinum by the Canadian Institute of Mining and Metallurgy for his contributions to the art of milling gold ores. The medal is about three inches in diameter and is valued at more than $500. Mr. Denny will also be presented with a replica in nickel. The medal was designed by R. Tait McKenzie, Canadian sculptor. Mr. Denny contributed a series of articles on McIntyre metallurgy in the November, 1933, issue of *Engineering and Mining Journal,* (pages 472-484), and a recent portrait of him is presented on page 450 of the issue noted.

OBITUARY

Henry Stephens Washington, petrologist, geologist, physicist, and author, at Washington, D. C., on Jan. 7; aged 66.

R. A. Sawyer, geologist, engineer, and writer, for many years active on the Rand, died recently at Redhill, Surrey, England.

C. J. T. Kapp, metallurgical engineer (Freiburg, 1897), died recently at Johannesburg. Since 1893 Mr. Kapp had been consulting engineer to Becker's Trust.

Alexandre Corrigan, a mining man with extensive interests in Quebec mining claims, was accidentally killed by an explosion of dynamite caps at Rouyn on Nov. 28. He was 53 years old.

Francis J. Webb, general manager of northern ore mines for the Republic Steel Corporation. Mr. Webb died while en route by auto from the Mesabi range to Duluth. He was 60 years old. He is succeeded by **John E. Nelson,** superintendent of Michigan mines for Republic Steel.

Ellis Mallery, engineer and geologist and pioneer in the discovery of southern California oil fields; at Los Angeles, Calif., on Nov. 21; aged 55 years. Mr. Mallery was born at Red Cloud, Neb., and had been since a young man engaged in mining projects throughout the Pacific Coast area from Alaska to Mexico.

Everett Morss, president of Simplex Wire & Cable Company since 1903; in Boston, on Dec. 27; aged 68. Mr. Morss was a graduate of the mining engineering course at the Massachusetts Institute of Technology, and was treasurer of the corporation of that institution at the time of his death.

Richard Malone Geppert; at Whitecraigs, Wellington, Surrey, England; on Dec. 11; aged 57. Mr. Geppert was a graduate of Columbia School of Mines, Class of '98, which included, also, A. Chester Beatty, with whom Mr. Geppert was later to be long associated professionally; Henry Crumb, William Allen Smith, and Harold A. Titcomb. Mr. Geppert's long and brilliant career carried him into virtually all of the mining regions of the earth. He superintended most of the diamond drilling which proved the ore reserves of Roan Antelope and Mufulira Copper. A memorial service was held for Mr. Geppert in London shortly after his death.

Charles Butters—1854-1933

A bright-eyed, alert man of small stature, clad in tweeds, stood back of a pine table in the mining lecture room at the University of California. A roll of blueprints lay in front of him. Prof. S. B. Christy, with a glint of pride in his eyes, introduced the speaker to his group of mining students. Then followed an animated talk about the cyanide developments in South Africa, an explanation of the tailings plants, and some direct advice to his eager audience. In the heyday of life, direct from important work in South Africa, and under the proud gaze of his friend Christy, Charles Butters made a lasting impression upon the young students of that day, long since past.

Some years later, one of those students walked through the Six-Mile Canyon cyanide plant, near Virginia City, Nev., hunting for Mr. Butters. He found him standing in a vat upon a bed of hard-packed sand which partly filled it. Butters was energetically digging into the sand bed. He stopped as he became conscious of the visitor looking down upon him, and, looking up, said: "Young, I have been looking for hard jobs all my life. I like difficulties, but I am through with trying to crack hard nuts and from now on I am going to look for easy problems. This is a tough one."

A month or so ago, several members of the Institute visited Butters as he lay upon his bed, sick. The indomitable spirit and mobile mind of Charles was apparent. Although he talked about his illness, he speedily branched out into a discussion of metallurgical work and new plans he was thinking about. He pointed to a photograph of his wife and told us what a wonderful helpmate and companion she was. Bits of personal history were touched upon until the nurse waved us out. We hardly realized the rapidly approaching end.

Butters graduated from the Mining College of the University of California in 1879. Of an early vintage, ripened in the cask of experience, sparkling with life, his was a wine that energized the mining industry, cast its color into the dark places, and vivified all who came in contact with it. He talked freely about his troubles, his difficulties, his successes, and his failures. He never fooled himself. Of his experiences at Virginia City, he said: "In 1901, I built a slime plant at Virginia City to treat the old Comstock dumps. The material was a sticky stuff, much oxidized, colloidal, very tenacious, and hard to settle. I made a complete fizzle out of the job at first, losing $100,000 in the first year. Altogether we lost $475,000, which was the price for learning how to filter slime. I developed my system of filtration, and in doing so I was assisted by Mr. Patterson. As a sequel to our experience at Virginia City, all Tonopah plants, particularly the Tonopah mill at Millers, were designed. This was done in 1907 after we had treated 50,000 tons of their ore at Virginia City."

After graduation from the Mining College, Butters worked as a chemist for the New Almaden Quicksilver Company in California. He speedily left this job and went to Fairplay, Colo., where he opened an engineering office in association with W. H. Leffingwell. He gained experience in milling and then went to New York as agent for the Pacific Iron Works. Selling

Charles Butters

was not to his liking, and he returned to Colorado and established a custom mill at Crested Butte. In 1883 he was back again in New York, where he opened an office and experimented in the treatment of the ores from the San Sebastian mine. At this time he was intersted in the chlorination method of treating gold ores. He went to Salvador and built a 30-ton chlorination plant at the San Sebastian mine. In 1887 he built a custom chlorination plant at Kennett, Calif. Business failed to come up to expectations, and the sheriff took the plant. In 1889, through his friend Professor Christy, he was asked to go to South Africa, which he did and became assistant to Hennen Jennings. He established the chlorination process at the Robinson mine. About this time the cyanide process attracted attention, and Butters was among the first to realize its importance in gold metallurgy. In 1894 he started the Rand Central Ore Reduction Company and successfully applied both chlorination and cyanidation to the ores and concentrates from the mines. He also erected a cyanide plant for the treatment of the tailings from the Robinson mill by cyanidation. The South African experiences established Butters as one of the foremost gold and silver metallurgists of that time.

The insatiable Butters was not satisfied. In 1897, he and his associates bought the San Sebastian mine, which eventually produced over $10,000,000 in gold, half of which was distributed in dividends. He then went to Mexico and built a cyanide plant at Minas Prietas, in Sonora. This was the first plant in Mexico to treat slime by agitation and cyanidation. His two associates, E. M. Hamilton and C. G. Patterson, went to Guanajuato and erected a similar plant. In the midst of his Mexican experience he built the tailings plant at Virginia City. This involved sand and slime treatment, the slime being handled by decantation. Here he tried out a sulphurous acid treatment of the slimes in an endeavor to get rid of the copper in the tailings. He also tried out electrolytic precipitation of cyanide solutions.

When the Elmores began experimenting with flotation Butters became interested at once, but the impracticability of the early process was soon demonstrated, and it was not until 1914 that Butters renewed his interest in flotation. By that time substantial progress had been made and he made intensive investigations of its applicability to gold and silver ores in conjunction with cyanidation. His associate, J. E. Clennell, made many experiments. From that time until his death he kept in close touch with flotation developments and made use of the process where he could.

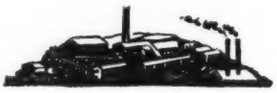
During the war period Butters interested himself in an aluminum powder and its manufacture at a plant at his home on Chabot Road, Oakland, Calif. This plant was later removed to Martinez. Following the war Butters returned to gold mining in Nicaragua. His San Albino mine was placed in operation and would have continued but for the revolutionary turmoil which finally caused operations to cease. Sandino, the insurgent leader, was at one time employed in Butters' office at the mine. Butters sought to protect his interests and had many thrilling experiences, culminating in a narrow escape from a firing squad. Finally he left Nicaragua and returned to California.

Among some other interesting adventures in metallurgy Butters financed an intensive research in the electrolytic deposition of zinc at his Martinez plant. U. C. Tainton was the principal research technologist, and though his work at the time did not bear any results to Butters, subsequently Tainton completed his work at Kellog and the zinc plant of the Bunker Hill & Sullivan Company was designed and constructed.

T. A. Rickard in 1915 stated that "Charles Butters is an engineer whom I have always credited with a kind of technical prescience, a keen sensibility for the metallurgical requirements of tomorrow." He possessed a technical background, an open, alert mind, courage to do, and kept in the vanguard of progress. He made it his business to know mining engineers and people connected with the mining business and also to make the acquaintance of the ablest men in the profession. On the other hand, the profession respected and loved him and listened to him with the keenest interest. During his life great metallurgical events took place and the end of his life marks the beginning of a new regime in the mining industry.

Dec. 7, 1933 GEO. J. YOUNG

INDUSTRIAL PROGRESS



Instrument for Better Resistivity Work

Sensitivity Permits Greater Accuracy in Geophysical Surveys

"Ground Comparator" is the name applied by its inventor, Theodor Zuschlag, to a new electrical geophysical instrument. Apparatus of this sort has largely been confined in the past to either direct-current methods or to alternating-current techniques. To a certain extent, some instruments have combined the two techniques but have sacrificed the advantage of amplifying the ground current to that of employing direct-current recording instruments. In the new instrument, Mr. Zuschlag combined the advantage of both current techniques, and produced an electrical exploring apparatus which amplifies the ground current, thereby avoiding the necessity of using a powerful and heavy source of current, and at the same time employs direct-current recording instruments for reading the field values.

The increased sensitivity claimed for the Comparator, according to the inventor, will permit differentiating geological formations whose resistivities are not widely different, thereby greatly broadening the field of electrical geophysics. Among the new problems thus brought within the scope of electrical methods is that of locating and tracing quartz veins in gold-bearing districts.

To apply the new instrument in field work, the partnership of Low & Kelly, New York, entered into an agreement last year with Mr. Zuschlag. Now that the instrument has been tested in commercial work, they hope to carry out field surveys with it, and are willing to lay out, supervise, and interpret surveys for large companies having their own staffs to perform the field routine.

Sherwin F. Kelly, of the firm, recently used the Comparator in making a six weeks' electrical geophysical study of salt deposits near Syracuse, N. Y., for the Solvay Process Company.

Cheap Power for Lighting

A light compact diesel generating set producing current for lighting service at approximately ¾ to 1c. per kilowatt is a new development of the Buda Company, Harvey, Ill. These sets range in size from 10 to 90 kw., alternating and direct current. They do not require an attendant, save for an occasional visit, and are suitable for 24-hr. service. A small compact generator set, ranging from 5 to 75 kw. and fitted with a natural gas or gasoline engine of similar design, has also been introduced.

Diesel of New Type

An accompanying cut shows a new type Crossley scavenge-pump diesel engine direct-coupled to a 9-stage, high-lift turbine pump. The duty of the set is 694 g.p.m. against 278-ft. head, running at 500 r.p.m. The engine is a four-cylinder vertical type developing 110 b.hp. at 500 r.p.m. It is fitted with a scavenge pump at the control end, operated from the crankshaft to deliver air under pressure into a common manifold, from which the scavenging air sweeps into the cylinders in turn as each piston uncovers the ports, expelling the exhaust products out into the exhaust manifold and leaving in the cylinders a full charge of cool, clean air, resulting in excellent combustion of the fuel oil, clean working, high power output, and high thermal efficiency.

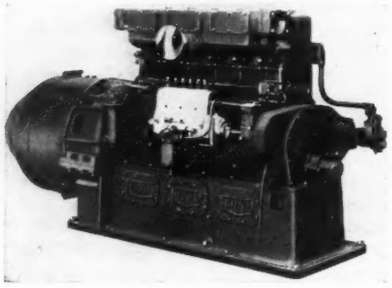
In the new engine, lubrication has been simplified, inasmuch as the crankcase is free from scavenging air, and a copious supply of oil under pressure is forced to all bearings. The new unit is said to exploit to the full the great possibilities of two-cycle design, at the same time embodying the best points usually associated with the four-cycle type. Crossley Brothers are located at Manchester, England.

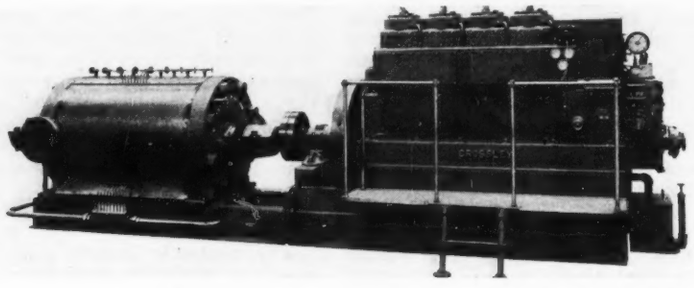
Simple Air Compressor Is Vibrationless

Diminution in weight and volume, and economy in initial and operating cost, are claimed by the manufacturers of a simple engine-compressor, proved as practicable in France. It consists essentially of a single cylinder with two pistons, between which oil fuel is fired. In starting, the pistons are levered apart against a strong spring, permitting intake of air and fuel into the explosion chamber.

On being released, the air is compressed by movement of the pistons toward each other, firing the oil fuel by heat generation. Simultaneously, air is drawn into the air chambers. The effect of expansion by explosion in the fuel chamber is to compress this air, part of which is used for scouring, the remainder of the air passing to a receiver.

Piston movement is linked to a plate, and the motions are carried to the fuel injection system. Absence of vibration is a feature of the new engine-compressor, which is likely to find application as a portable unit.





Daily and Average Monthly Prices of Metals

December, 1933

United States Market

Dec.	Electrolytic Copper Domestic	Electrolytic Copper Export	Straits Tin New York	Lead New York	Lead St. Louis	Zinc St. Louis
1	7.775	7.425	53.500	4.00@4.05	3.95	4.500
2	7.775	7.425	53.625	4.05	3.95	4.500
4	7.775	7.350	52.750	4.15	4.05	4.500
5	7.775	7.400	53.375	4.15	4.05	4.500
6	7.775	7.475	53.000	4.15	4.05	4.500
7	7.525@7.775	7.350	52.625	4.15	4.05	4.500
8	7.525@7.775	7.400	53.125	4.15	4.05	4.450@4.500
9	7.775	7.400	53.350	4.15	4.05	4.475@4.500
11	7.775	7.475	53.000	4.15	4.05	4.450@4.500
12	7.775	7.450	52.375	4.15	4.05	4.500
13	7.775	7.425	52.375	4.15	4.05	4.500
14	7.775	7.525	53.000	4.15	4.05	4.500
15	7.775@8.025	7.675	53.000	4.15	4.05	4.500
16	7.775@8.025	7.700	53.100	4.15	4.05	4.500
18	8.025	8.075	53.250	4.15	4.05	4.500
19	8.025	8.150	53.125	4.15	4.05	4.450@4.500
20	8.025	8.200	52.750	4.15	4.05	4.450
21	8.025	8.075	52.375	4.15	4.05	4.450
22	8.025	7.975	52.725	4.15	4.05	4.450
23	8.025	7.950	52.725	4.15	4.05	4.450
25	Holiday					
26	8.025	8.000	53.250	4.15	4.05	4.370@4.450
27	8.025	8.025	52.900	4.15	4.05	4.350@4.375
28	8.025	7.925	52.500	4.15	4.05	4.325@4.375
29	8.025	7.950	52.600	4.15	4.05	4.350
30	8.025	7.950	53.000	4.15	4.05	4.350
Av. for month	7.885	7.710	52.936	4.141	4.042	4.461
Averages for Week						
6	7.775	7.417	53.250	4.105	4.01	4.500
13	7.733	7.417	52.808	4.150	4.05	4.490
20	7.942	7.888	53.038	4.150	4.05	4.488
27	8.025	8.005	52.795	4.150	4.05	4.425
Calendar Week Averages						
2	7.775	7.463	53.205	4.15	4.05	4.500
9	7.733	7.396	53.038	4.15	4.05	4.494
16	7.817	7.542	52.808	4.15	4.05	4.496
23	8.025	8.071	52.825	4.15	4.05	4.463
30	8.025	7.970	52.850	4.15	4.05	4.365

Silver, Gold, and Sterling Exchange New York and London

Dec.	Sterling Exchange "Checks"	Sterling Exchange "90-day Demand"	Silver New York	Silver London	Gold London	Gold (a) United States
1	5.1700	5.2100	43.7500	18.4375	125s 2 d	$34.01
2	5.1700	5.2150	43.3750	18.5625	124s 11½d	34.01
4	5.0700	5.1150	43.1250	18.5625	124s 8 d	34.01
5	5.1300	5.1750	43.6250	18.5625	125s 6 d	34.01
6	5.1200	5.1600	43.6250	18.6250	126s 11 d	34.01
7	5.1050	5.1500	43.6250	18.6875	126s	34.01
8	5.1125	5.1525	43.2500	18.5625	126s 9 d	34.01
9	5.1650	5.2050	43.8750	18.5000	126s 6 d	34.01
11	5.1150	5.1600	43.5000	18.6250	127s	34.01
12	5.0700	5.1000	42.7500	18.5000	126s 4½d	34.01
13	5.0300	5.0600	42.5000	18.5625	126s 1 d	34.01
14	5.0775	5.1175	43.2500	18.6250	126s 1 d	34.01
15	5.1200	5.1550	43.5000	18.6875	126s 7 d	34.01
16	5.1150	5.1550	43.2500	18.6250	126s 4 d	34.01
18	5.1475	5.1800	43.6250	18.6250	126s 9 d	34.06
19	5.1300	5.1750	43.5000	18.6250	126s 9 d	34.06
20	5.0850	5.1300	43.0000	18.5625	126s 9 d	34.06
21	5.0875	5.1300	43.0000	18.5625	126s 2 d	34.06
22	5.1050	5.1500	44.2500	19.0625	126s 3 d	34.06
23	5.1100	5.1500	43.7500	18.8125	126s 4 d	(b) .....
25	Holiday	Holiday	Holiday	Holiday	Holiday	Holiday
26	5.1450	5.1850	43.5000	Holiday	Holiday	34.06
27	5.1150	5.1600	43.7500	18.7500	126s 5 d	34.06
28	5.0925	5.1400	44.3750	18.9375	126s 3 d	34.06
29	5.0775	5.1300	44.3750	19.0625	126s 2 d	34.06
30	5.1500	5.1950	44.6250	19.0625	126s 6 d	(b) .....
Av. for month	5.11260	.....	43.550	18.674	.....	.....
Averages for Week						
6	5.13200	.....	43.500	.....	.....	.....
13	5.09958	.....	43.250	.....	.....	.....
20	5.11250	.....	43.354	.....	.....	.....
27	5.11250	.....	43.650	.....	.....	.....

Calendar week averages: New York Silver Dec. 2, 43.100; Dec. 9, 43.521; Dec. 16, 43.125; Dec. 23, 43.521; Dec. 30, 44.125.

(a) Reconstruction Finance Corporation's daily quotation. (b) No price posted; federal departments closed for holiday.

London Market

Dec.	Copper Standard Spot	Copper Standard 3M	Copper Electrolytic Bid	Tin Spot	Tin 3M	Lead Spot	Lead 3M	Zinc Spot	Zinc 3M
1.....	29.5000	29.6875	32.5000	226.1250	226.2500	11.4375	11.7500	14.6250	14.9375
4.....	29.8750	30.0000	32.7500	227.6250	227.6250	11.5625	11.8125	14.6875	15.0625
5.....	30.1250	30.2500	33.0000	227.1250	227.2500	11.5625	11.8750	14.8125	15.1250
6.....	30.1250	30.1875	33.0000	227.2500	227.2500	11.6250	11.8750	14.8750	15.1875
7.....	30.0625	30.1875	32.7500	226.5000	226.6250	11.4375	11.6250	14.8125	15.0000
8.....	30.0625	30.1875	33.2500	227.3750	227.3750	11.4375	11.6875	14.8750	15.1250
11.....	30.3125	30.5000	33.5000	228.3750	228.3750	11.4375	11.6250	14.7500	14.9375
12.....	30.4375	30.5625	33.5000	228.0000	228.1250	11.4375	11.6875	14.6250	14.9375
13.....	30.7500	30.8750	33.5000	229.0000	229.0000	11.6250	11.8125	14.8125	15.1250
14.....	31.3125	31.4375	34.2500	228.2500	228.3750	11.6250	11.8750	14.7500	15.0625
15.....	31.6250	31.6875	34.0000	228.2500	228.2500	11.5000	11.7500	14.8750	15.1250
18.....	32.8125	32.8750	35.5000	228.5000	228.5000	11.5000	11.8125	14.9375	15.1875
19.....	33.2500	33.3750	36.0000	228.0000	228.0000	11.3125	11.6875	15.1875	15.3125
20.....	33.1875	33.3125	36.2500	228.0000	228.1250	11.3750	11.7500	15.0000	15.1875
21.....	32.3125	32.4375	35.7500	226.8750	226.8750	11.3750	11.5625	14.8750	15.0625
22.....	32.0000	32.1875	35.5000	227.6250	227.3750	11.3125	11.4375	14.7500	14.8750
25.....	Holiday								
26.....	Holiday								
27.....	32.1875	32.3750	35.5000	228.0000	227.8750	11.2500	11.3750	14.7500	14.9375
28.....	32.3750	32.5000	35.7500	227.2500	227.5000	11.1250	11.1875	14.8125	14.9375
29.....	32.5000	32.6875	36.0000	227.7500	227.8750	11.2500	11.3125	14.8750	15.0000
Av. for month.	31.306	.....	34.329	227.678	.....	11.431	11.658	14.826	15.059

The United States quotations are our appraisal of the major markets for domestic consumption based on sales reported by producers and agencies. They are reduced to the basis of cash, New York or St. Louis, as noted. All prices of domestic class are in cents per pound.

Copper, lead and zinc quotations are based on sales for both prompt and future deliveries; tin quotations are for prompt delivery only.

Quotations for zinc are for ordinary Prime Western brands. Zinc in New York is now quoted as 0.35c. per pound above St. Louis, this being the freight differential. Contract prices for High-Grade zinc delivered in the East and Middle West usually command a pre-

Silver and Sterling Exchange

	New York		London Spot		Sterling Exchange	
	1932	1933	1932	1933	1932	1933
January	29.780	25.400	19.623	16.883	342.515	336.060
February	30.136	26.074	19.573	16.885	345.141	342.114
March	29.810	27.928	18.336	17.588	363.463	343.138
April	28.298	30.730	16.923	18.440	374.731	357.565
May	27.755	34.072	16.868	19.046	367.370	393.106
June	27.466	35.663	16.844	19.078	364.471	413.216
July	26.700	37.630	16.930	18.341	354.865	464.760
August	27.986	36.074	18.000	17.877	347.449	449.944
September	27.870	38.440	17.998	18.272	347.003	466.240
October	27.195	38.190	17.813	18.221	339.500	466.380
November	26.698	42.974	18.099	18.428	327.458	514.573
December	25.010	43.550	17.110	18.674	327.683	511.260
Year	27.892	34.727	17.843	18.144	350.137	421.530

New York quotations, cents per ounce troy, 999 fine. London, pence per ounce, sterling silver, 925 fine. Sterling exchange in cents.

Copper

	F.O.B. Refinery			London Spot			
	Electrolytic			Standard		Electrolytic	
	Domestic		Export				
	1932	1933	1933	1932	1933	1932	1933
January	7.060	4.775	4.741	39.459	28.557	46.200	33.244
February	5.965	4.775	4.710	36.917	28.481	41.381	32.556
March	5.763	5.011	4.779	33.039	28.179	36.786	32.370
April	5.565	5.395	5.185	29.943	29.576	34.190	33.681
May	5.237	6.698	6.569	28.548	34.071	32.833	38.163
June	5.145	7.773	7.484	26.872	36.759	30.841	41.000
July	5.053	8.635	8.446	26.071	37.917	29.107	41.524
August	5.219	8.768	7.937	31.401	36.071	34.784	40.227
September	5.978	8.753	7.788	34.986	35.122	38.318	38.339
October	5.733	7.950	7.557	31.890	33.656	36.190	36.977
November	5.131	7.881	7.647	31.972	30.588	36.568	33.898
December	4.813	7.885	7.710	29.688	31.306	34.344	34.329
Year	5.555	7.025	6.713	31.682	32.524	35.962	36.359

New York quotations, cents per pound. London, pounds sterling per long ton.

Lead

	New York		St. Louis		London			
	1932	1933	1932	1933	1932 Spot	1932 3 Mos.	1933 Spot	1933 3 Mos.
January	3.750	3.000	3.550	2.875	15.084	15.128	10.458	10.833
February	3.712	3.000	3.499	2.875	14.560	14.571	10.431	10.719
March	3.150	3.146	2.993	3.021	12.345	12.634	10.609	10.821
April	3.000	3.260	2.900	3.135	11.223	11.503	10.872	11.122
May	3.000	3.654	2.900	3.525	10.673	11.036	12.095	12.372
June	2.993	4.173	2.896	4.023	9.608	9.898	13.280	13.571
July	2.747	4.452	2.611	4.303	9.818	10.152	13.411	13.613
August	3.235	4.500	3.093	4.350	11.349	11.588	12.182	12.457
September	3.465	4.500	3.315	4.350	13.122	13.349	11.932	12.229
October	3.052	4.313	2.939	4.176	11.958	12.170	11.804	12.102
November	3.050	4.288	2.931	4.146	12.071	12.395	11.537	11.778
December	3.000	4.141	2.877	4.042	11.144	11.541	11.431	11.658
Year	3.180	3.869	3.042	3.735	11.913	12.164	11.670	11.940

New York and St. Louis quotations, cents per pound. London, pounds sterling per long ton.

Tin

	New York		London	
	1932	1933	1932	1933
	Straits		Standard, Spot	
January	21.804	22.692	140.219	145.708
February	22.018	23.500	139.143	148.544
March	21.863	24.221	129.810	149.120
April	19.244	27.136	108.935	157.944
May	20.948	36.051	122.286	186.207
June	19.659	44.097	114.530	219.964
July	20.931	46.356	125.863	216.673
August	22.985	44.794	142.017	215.210
September	24.779	46.665	152.705	216.893
October	23.936	47.858	151.280	223.455
November	23.354	53.011	153.585	226.722
December	22.677	52.936	149.806	227.678
Year	22.017	39.110	135.848	194.510

New York quotations, cents per pound. London, pounds sterling per long ton.

Zinc

	St. Louis		London			
	1932	1933	1932 Spot	1932 3 Mos.	1933 Spot	1933 3 Mos.
January	3.011	3.018	14.416	14.834	14.381	14.595
February	2.817	2.666	13.872	14.289	13.866	14.119
March	2.787	2.987	12.616	13.024	14.647	14.674
April	2.725	3.298	11.670	11.958	14.951	15.208
May	2.532	3.805	12.432	12.682	15.505	15.660
June	2.777	4.348	11.548	11.866	16.988	16.774
July	2.537	4.878	11.592	11.967	17.795	17.739
August	2.758	4.916	13.594	13.844	16.869	17.031
September	3.322	4.699	15.455	15.616	16.810	17.042
October	3.027	4.748	14.869	15.140	16.310	16.599
November	3.094	4.520	15.264	15.534	15.048	15.349
December	3.124	4.461	15.209	15.347	14.826	15.059
Year	2.876	4.029	13.545	13.842	15.666	15.825

St. Louis quotations, cents per pound. London, pounds sterling per long ton.

Cadmium and Aluminum

	Cadmium		Aluminum	
	1932	1933	1932	1933
January	55.000	55.000	23.300	23.300
February	55.000	55.000	23.300	23.300
March	55.000	55.000	23.300	23.300
April	55.000	55.000	23.300	23.300
May	55 000	55.000	23.300	23.300
June	55.000	55.000	23.300	23.300
July	55.000	55.000	23.300	23.300
August	55.000	55.000	23.300	23.300
September	55.000	55.000	23.300	23.300
October	55.000	55.000	23.300	23.300
November	55.000	55.000	23.300	23.300
December	55.000	55.000	23.300	23.300
Year	55.000	55.000	23.300	23.300

Aluminum in cents per pound, 99 per cent grade.
Cadmium, cents per pound.

Antimony, Quicksilver, and Platinum

	Antimony (a) New York		Quicksilver (b) New York		Platinum (c) New York	
	1932	1933	1932	1933	1932	1933
January	5.976	5.722	64.900	48.500	40.000	26.480
February	6.489	5.738	66.304	48.614	40.000	24.000
March	6.188	5.901	72.537	52.676	40.000	24.667
April	5.746	5.876	72.125	54.580	40.000	26.800
May	5.170	6.264	66.380	56.500	39.500	28.500
June	5.034	6.500	59.481	60.038	37.500	30.000
July	5.000	7.262	53.580	62.900	35.200	32.320
August	5.144	6.986	47.444	63.500	35.000	33.000
September	5.606	6.880	47.500	64.580	33.800	34.560
October	5.575	6.843	47.600	66.500	33.000	36.000
November	5.771	7.113	48.750	66.000	33.000	37.583
December	5.400	7.250	48.500	66.330	30.462	38.000
Year	5.592	6.528	57.925	59.227	36.455	30.993

(a) Antimony quotations in cents per pound, for ordinary brands. (b) Quicksilver in dollars per flask of 76 lb. (c) Platinum in dollars per ounce troy.

Pig Iron

	Bessemer		Basic		No. 2 Foundry	
	1932	1933	1932	1933	1932	1933
January	16.00	14.50	15.00	14.00	15.50	14.50
February	15.68	14.50	14.68	14.00	15.18	14.50
March	15.50	14.50	14.50	14.00	15.00	14.50
April	15.50	14.50	14.50	14.00	15.00	14.50
May	15.50	15.42	14.50	14.42	15.00	14.92
June	14.85	16.00	14.35	15.00	14.75	15.50
July	14.56	16.50	14.00	15.50	14.50	16.00
August	14.50	17.00	14.00	16.00	14.50	16.50
September	14.50	18.00	14.00	17.00	14.50	17.50
October	14.50	18.00	14.00	17.00	14.50	17.50
November	14.50	18.00	14.00	17.00	14.50	17.50
December	14.50	18.00	14.00	17.00	14.50	17.50
Year	15.01	16.24	14.29	15.41	14.79	15.91

Iron in dollars per long ton. F.o.b. Mahoning and Shenango Valley furnaces

mium of 1c. over Prime Western.

Quotations for lead reflect prices obtained for common lead, and do not include grades on which a premium is asked.

London prices for lead and zinc are the official prices for the first session of the London Metal Exchange; prices for copper and tin are the official closing buyers' prices. All are in pounds sterling per long ton (2,240 lb.).

New York silver quotations are as reported by Handy & Harman and are in cents per troy ounce of silver, 999 fine. London silver quotations are in pence per troy ounce of bar silver, 925 fine. Sterling prices represent noon market demand.